Bacteria TMDL for
Neabsco Creek
Prince William County, Virginia

Submitted by the

Virginia Department of Environmental Quality

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ACRONYMS:

ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacterial Source Tracking
CFR	Code of Federal Regulations
cfu	Colony Forming Units
CREP	Conservation Reserve Enhancement Program
DGIF	Department of Game and Inland Fisheries
E. coli	*Escherichia coli*
EC	*E. coli*
EQIP	Environmental Quality Incentive Programs
ft^3/s	cubic feet per second
FC	Fecal coliform
GIS	Geographic Information System
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MOU	Memorandum of Understanding
MS4	Municipal Separate Storm Sewer Systems
MST	Microbial Source Tracking
NCDC	National Climatic Data Center
NLCD	National Land Cover Data
PWC	Prince William County
SWCB	State Water Control Board
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analysis
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VA DCR	Virginia Department of Conservation and Recreation
VA DEQ	Virginia Department of Environmental Quality
VDOT	Virginia Department of Transportation
VPDES	Virginia Pollutant Discharge Elimination System
WBID	Waterbody Identification Code
WLA	Wasteload Allocation
WQIP	Water Quality Improvement Fund
WQMIRA	Water Quality Monitroing, Information, and Restoration Act
WQMP	Water Qualty Management Plan

Executive Summary

This report presents the development of a Total Maximum Daily Load (TMDL) for bacteria in Neabsco Creek (TMDL ID: VAN-A25R-01). Neabsco Creek is located in Prince William County, Virginia in the Middle Potomac River Basin (USGS Hydrologic Unit Code 02070010). The water body identification code (WBID, Virginia Hydrologic Unit) for Neabsco Creek is VAN-A25R. The impaired segment extends from the confluence of Neabsco Creek with an unnamed tributary to Neabsco Creek, near Dale City and approximately 0.4 rivermiles downstream from Route 784 (on the tributary), downstream to the end of the free-flowing portion of Neabsco Creek at the Route 1 bridge crossing. The impaired segment is 8.42 miles in length.

The drainage area of the impaired portion of the Neabsco Creek watershed is approximately 15.6 square miles. The watershed is located entirely in Prince William County, and includes much of the Dale City area. The average annual rainfall as recorded at Washington Reagan National Airport (National Climatic Data Center (NCDC) station 448906, approximately 19 miles northwest of study area) is 39.8 inches. The watershed study area is approximately 10,009 acres, the majority of which is developed.

Neabsco Creek was listed as impaired in Virginia's <u>2002 303(d) Report on Impaired Waters</u>, the <u>2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report</u>, and the <u>2006 305(b)/303(d) Water Quality Assessment Integrated Report</u> (VADEQ, 2002, 2004, and 2006) for not supporting the recreation use due to exceedances of the State's water quality criteria for fecal coliform bacteria. The main sampling station on Neabsco Creek is located at the Route 1 bridge crossing (Station 1ANEA002.89). Out of 23 samples collected at Station 1ANEA002.89 during the 2002 assessment period, five (22%) exceeded the water quality criterion for fecal coliform bacteria at station 1ANEA002.89. Seven of 23 samples (30%) exceeded the fecal coliform bacteria water quality criterion during the 2004 water quality assessment period, and five of 17 samples (29%) exceeded the criterion during the 2006 assessment period. This impaired segment of Neabsco Creek is listed in Attachment C (Plaintiff's list of waters that were added to the 303(d) list in 2002) of the 1999 Consent Decree (*American Canoe Association, Inc. and American Littoral Society vs. United States Environmental Protection Agency, et. al*, 1999).

According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Neabsco Creek must support all designated uses and meet all applicable criteria. Neabsco Creek does not currently support the primary contact recreation use. Thus, a TMDL must be developed for the bacteria impaired portion of Neabsco Creek.

The load-duration approach was used to develop the TMDL for Neabsco Creek. The load-duration method of TMDL development essentially uses the entire stream flow record to provide insight into the flow conditions under which exceedances of the water quality standard occur. A flow-duration curve was developed for Neabsco Creek by using Accotink Creek as a reference watershed. The load-duration curve for Neabsco Creek was developed by multiplying each flow level along the flow-duration curve by the applicable water quality criterion (235 cfu/100mL) and required unit conversions. The load-duration curve represents the allowable loading capacity of the stream at the water quality criterion for each flow interval.

Because the allowable load is variable with flow and represents simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions, the TMDL condition was selected to reflect the flow-varying nature of bacteria impairments. In order to capture all flow conditions, the TMDL will be determined for the 99th load percentile, i.e. for the 1% flow-duration interval. This represents the maximum flow condition determined for Neabsco Creek (only 1% of the flows exceed this value).

To determine the necessary load reductions at this maximum flow condition, a second curve was developed to represent the magnitude of the highest observed exceedance if it were to occur over any flow condition. For Neabsco Creek the one percent flow-duration interval daily *E. coli* load is 5.48×10^{12} cfu/day. This number represents the existing *E. coli* load in the watershed. The daily TMDL load under one percent flow-duration is 1.57×10^{12} cfu/day. This represents the *E. coli* loading that could be present in the watershed and Neabsco Creek would still meet the water quality standards for recreation. These two values are used to calculate required reductions. A 71% reduction in the existing bacteria load is required for Neabsco Creek to reach its TMDL goal. Under the load-duration approach, the required reductions by source are determined by using Biological Source Tracking (BST) data.

The BST data results indicate that the majority of bacteria present at Station 1ANEA002.89 are from wildlife populations in the watershed (79%). The remainder of the bacteria are from pet sources (20%) and a small portion (1%) from livestock. There was also an insignificant (less than 1%) human signal present in the BST results. Thus, 79% of the reductions need to come from wildlife sources, 20% from pet sources, and 1% from livestock sources.

The TMDL, WLA and LA are presented as daily loads in Table E-1 for Neabsco Creek.

Table E-1. TMDL for *E. coli* in the Neabsco Creek watershed (cfu/day).

WLA[2]	LA[3]	MOS	TMDL[1]
1.27×10^{12}	2.97×10^{11}	Implicit	1.57×10^{12}

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA represents the load for VPDES and MS4 point sources. The point sources permitted to discharge in the Neabsco Creek watershed are presented in section 5.2. The WLA reflects an allocation for growth in the watershed. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as determined by the VADEQ Virginia Pollutant Discharge Elimination System program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.
3 – MS4 permits in the Neabsco Creek watershed are listed in section 5.2.2. MS4 areas account for approximately 78% of the Neabsco Creek watershed. Thus, 78% of the land-based loads are attributed to the MS4 entities, and will be included along with the other VPDES point sources in the WLA. The remaining 22% of the land-based, non-point source loads will be listed under the load allocation, and account for the natural/background levels of bacteria that are present in the forested corridors along Neabsco Creek and its tributaries.

For Neabsco Creek, a reduction of approximately 71% is required to meet the water quality criteria for bacteria. These reductions will be applied to the MS4 permit areas and each of the four non-point sources identified in the BST analysis. The Neabsco Creek TMDL development presented in this report is the first step toward the attainment of water quality standards. The second step is to develop a TMDL implementation plan, and the final step is the field implementation of the TMDL to attain water quality standards.

The Commonwealth intends for this TMDL to be implemented through a process of phased implementation of best management practices (BMPs). The Neabsco Creek TMDL requires a 71% reduction in non-point source loading and MS4 loading in order to attain a 0% exceedance rate of water quality standards. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels (50%, 40%, and 33%) and their associated exceedance rates were assessed. Reduction curves similar to the maximum exceedance/reduction curve were plotted and are presented in this report.

Results also indicate that approximately 29% of the exceedances occurred during times of precipitation and increasing stream flow or just after a precipitation event with stable or decreasing stream flow. This suggests that those exceedances could be related to runoff events. Some of the BMPs effective in reducing bacteria runoff from such precipitation events include: riparian buffer zones, retention ponds/basins, range and pasture management, and animal waste management. Detailed lists of BMPs and their relative effectiveness will be included in the TMDL implementation plan for the watershed.

Public participation in the Neabsco Creek TMDL process plays a vital role in developing a TMDL that is accurate and reflects the actual conditions in the watershed. It is also important to include the public so that the final TMDL is acceptable to local stakeholders. Involving the public in the TMDL development process also encourages public participation when it is time to develop the Implementation Plan for the impaired water body. Two Technical Advisory Committee (TAC) Meetings were held for this project, both at the Northern Regional Office of DEQ in Woodbridge, Virginia. The TAC included representatives from the Prince William County Government, the Prince William County Soil and Water Conservation District, the Department of Conservation and Recreation, the Prince William County Health Department, the Dale Service Corporation, and a local adopt-a-stream program.

The first TAC Meeting was held on June 19, 2007. The purpose of this first TAC meeting was to discuss the process for TMDL development, review the draft source assessment input, and present the draft load-duration curve for the impaired water body. Thirteen people attended. Copies of the presentation materials were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register on June 11, 2007. There was a 30 day-public comment period following the first TAC meeting, however, no written comments were received.

The second TAC Meeting was held on July 18, 2007. The purpose of this second TAC meeting was to review the TMDL process and follow-up on comments received during the first TAC Meeting. Eleven people attended. Copies of the presentation materials were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register on July 9, 2007. There was a 30 day-public comment period following the first TAC meeting, however, no written comments were received.

A public meeting was held in Woodbridge, Virginia on December 13, 2007, to present the draft TMDL report. Five people attended. Copies of the presentation materials and draft report were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register and a meeting announcement was sent to several local newspapers. Flyers announcing the meeting were sent to all members of the TAC for distribution. There was a 30 day-public comment period following the public meeting, during which one set of comments were received.

1. Introduction

Section 303(d) of the Clean Water Act and US Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that exceed water quality standards. TMDLs represent the total pollutant loading that a water body can receive without exceeding water quality standards. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 1991).

The Commonwealth of Virginia's (Virginia's) 1997 Water Quality Monitoring, Information, and Restoration Act (WQMIRA) codifies the requirement for the development of TMDLs for impaired waters. Specifically section § 62.1-44.19:7 C states:

"The plan required by subsection A shall, upon identification by the Board of impaired waters, establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters. The Board shall develop and implement pursuant to a schedule total maximum daily loads of pollutants that may enter the water for each impaired water body as required by the Clean Water Act. "

The EPA specifies that in order for a TMDL to be considered complete and approvable, it must cover the following eight elements:

1. It must be designed to meet applicable water quality standards.
2. It must include a total allowable load as well as individual waste load allocations and load allocations.
3. It must consider the impacts of background pollution (in the case of Neabsco Creek this is wildlife).
4. It must consider critical environmental conditions or those conditions (stream flow, precipitation, temperature, etc.) which together can contribute to a worst-case exceedance of the water quality standard.
5. It must consider seasonal variations which together with the environmental variations can lead to a worst-case exceedance.
6. It must include an implicit or explicit margin of safety to account for uncertainties inherent in the TMDL development process.
7. It must allow adequate opportunity for public participation in the TMDL development process.
8. It must provide reasonable assurance that the TMDL can be met.

The following report documents the development of a bacteria TMDL for Neabsco Creek. Neabsco Creek was listed as impaired in Virginia's 2002 303(d) Report on Impaired Waters, the 2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report, and the 2006 305(b)/303(d) Water Quality Assessment Integrated Report (VADEQ, 2002, 2004, and 2006) for not meeting the recreational designated use. Approximately 8.42 miles of Neabsco Creek were listed as impaired due to exceedances of Virginia's water quality standard for fecal coliform bacteria. This impaired portion of Neabsco Creek was listed in Attachment C (Plaintiff's list of waters that were added to the 303(d) list in 2002) of the 1999 Consent Decree for fecal coliform (*American Canoe Association, Inc. and American Littoral Society vs. United States Environmental Protection Agency, et. al*, 1999).

A glossary of terms used throughout this report is presented as Appendix A.

2. Physical Setting

2.1. Listed Water Body

Neabsco Creek is a direct tributary to the Potomac River (USGS Hydrologic Unit Code 02070010). The water body identification code (WBID, Virginia Hydrologic Unit) for Neabsco Creek is VAN-A25R. The impaired segment is approximately 8.42 miles in length and stretches from the confluence of Neabsco Creek with an unnamed tributary (near Dale City, and approximately 0.4 rivermiles upstream from Route 784) downstream to the end of the free-flowing portion of Neabsco Creek at the Route 1 bridge crossing. Table 1 shows a description of the impairment, and Figure 1 shows a map of the impaired watershed.

Table 1. Impaired segment description (Neabsco Creek).

TMDL ID	Stream Name	Impairment	Length (miles)	Upstream Boundary	Downstream Boundary
VAN-A25R-01	Neabsco Creek	Fecal Coliform Bacteria	8.42	Confluence with an unnamed tributary located approximately 0.4 rivermiles downstream from Route 784	End of the free-flowing portion of Neabsco Creek (Route 1 bridge crossing)

2.2. Watershed

2.2.1. General Description

The Neabsco Creek watershed is located entirely within Prince William County, Virginia. The impaired portion of the watershed is roughly seven miles long and three miles wide, having an area of approximately 15.6 square miles (10009 acres).

Neabsco Creek flows southeast from its headwaters near the intersection of Route 642 (Hoadly Road) and Route 643 (Spriggs Road), through Dale City, and then joins the tidal waters for the Potomac River in Neabsco Bay. The Potomac River then flows into the Chesapeake Bay.

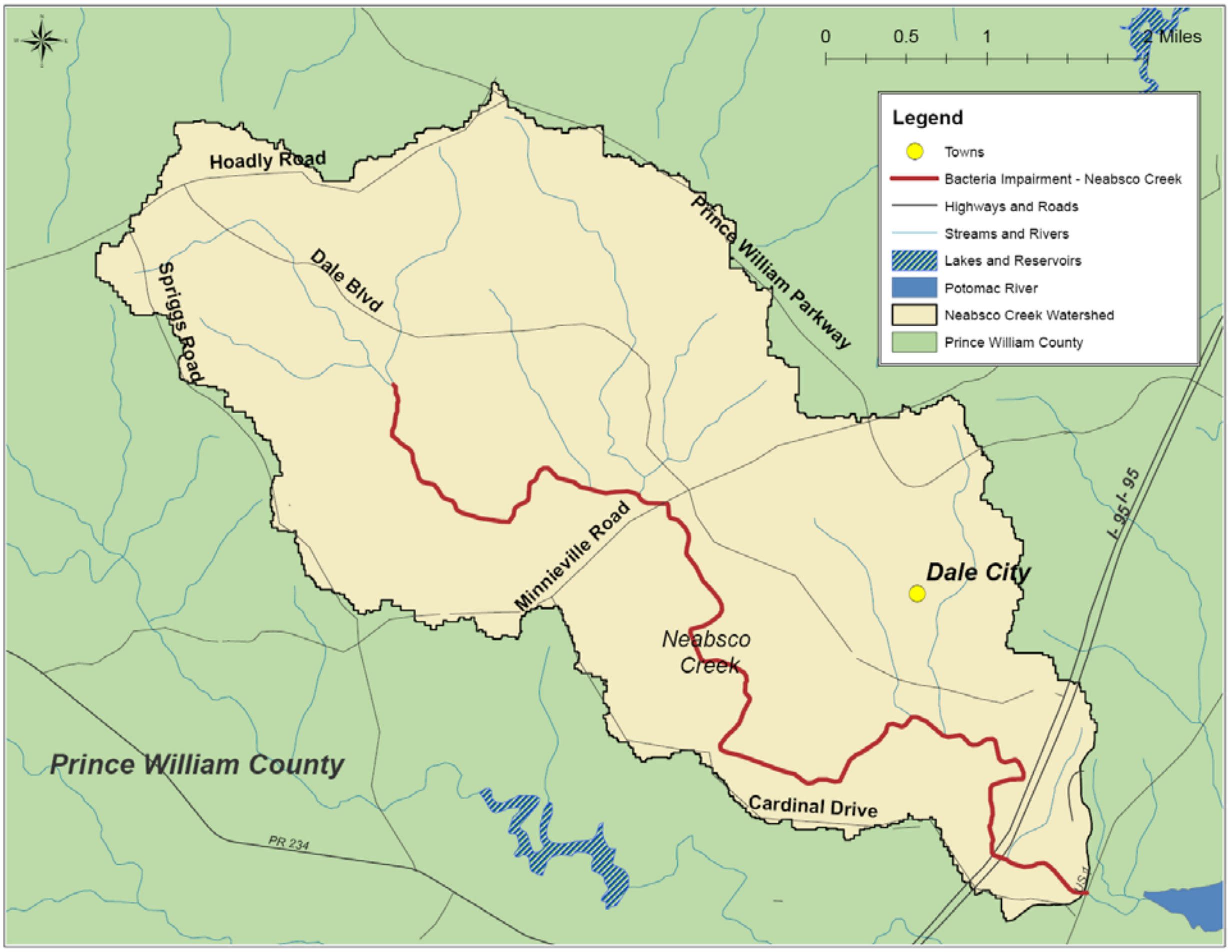

Figure 1. Map of the Neabsco Creek watershed.

2.2.2. Geology, Climate, Land Use

Geology and Soils

Neabsco Creek is located within the Piedmont Physiographic Province (USGS, 2007) of Virginia. Topography varies throughout the watershed, with elevations ranging from 465 feet to -4 feet above sea level (Figure 2). Major soil groups in the region are shown in Figure 3. Soil data was obtained through the United States Department of Agriculture Natural Resources Conservation Service Soil Mart website: http://soildatamart.nrcs.usda.gov/. The majority of soils in the watershed (27%) are classified as Urban land-Udorthents complex. Soils in this category have most likely been covered by asphalt, concrete, or other impervious surfaces. Udorthents are areas where the soils have been altered during excavation or covered by earthy fill material. Other popular soil types in the Neabsco Creek watershed include Neabsco loam (41B) and Meadowville loam (38B). A full description of all soil types found in the watershed can be found in Appendix E. Table 2 shows the percentage of each soil type in the impaired watershed.

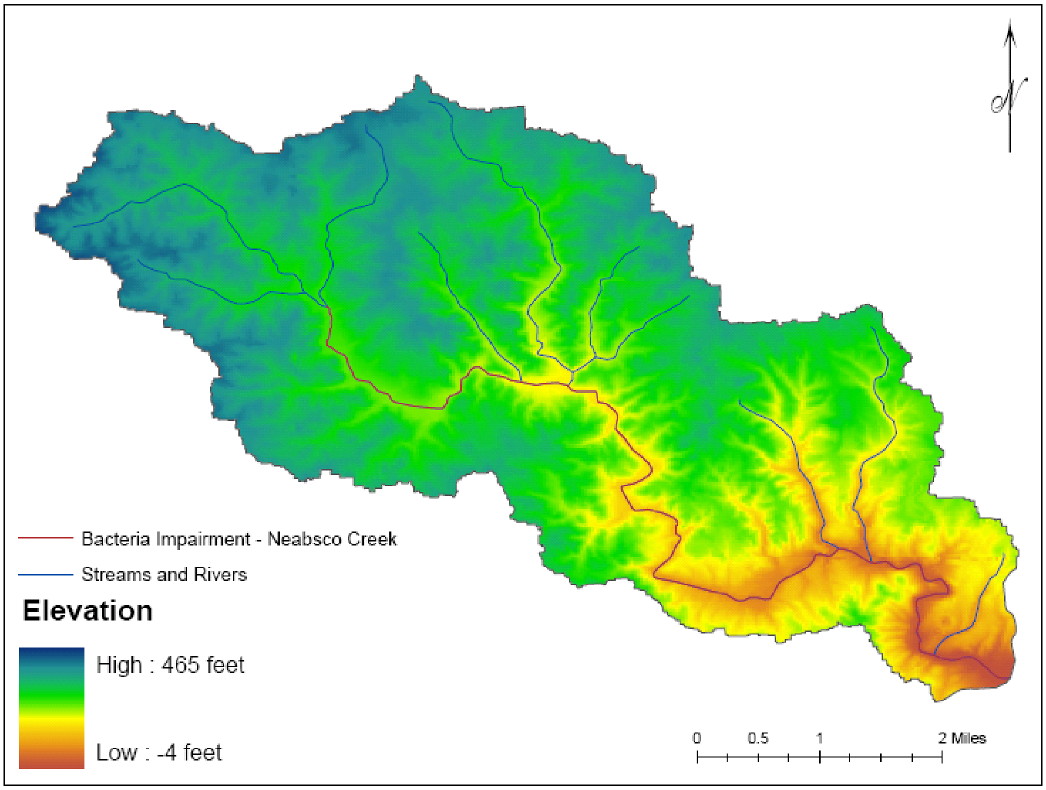

Figure 2. Topography in the Neabsco Creek watershed.

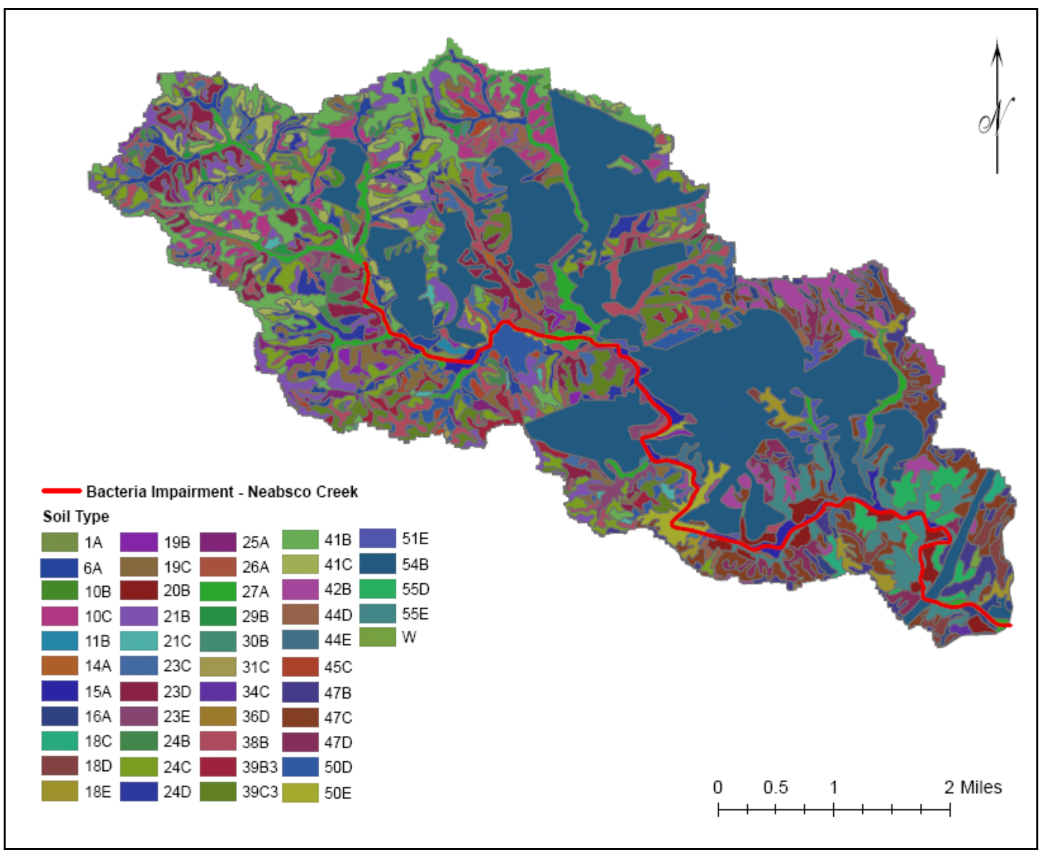

Figure 3. Soil types in the Neabsco Creek watershed.

Table 2. Soil types in the Neabsco Creek watershed.

Map Code	Soil Type	Acres in Watershed	Percent of Watershed
1A	Aden silt loam (0 to 2 percent slopes)	8.81	0.09
6A	Baile loam (0 to 4 percent slopes)	281.11	2.81
10B	Buckhall loam (2 to 7 percent slopes)	18.55	0.19
10C	Buckhall loam (7 to 15 percent slopes)	245.53	2.45
11B	Calverton silt loam (0 to 7 percent slopes)	14.69	0.15
14A	Codorus loam (0 to 2 percent slopes)	18.88	0.19
15A	Comus loam (0 to 2 percent slopes)	151.09	1.51
16A	Delanco fine sandy loam (0 to 4 percent slopes)	91.54	0.91
18C	Dumfries sandy loam (7 to 15 percent slopes)	31.29	0.31
18D	Dumfries sandy loam (15 to 25 percent slopes)	86.55	0.86
18E	Dumfries sandy loam (25 to 50 percent slopes)	93.38	0.93
19B	Elioak loam (2 to 7 percent slopes)	73.82	0.74
19C	Elioak loam (7 to 15 percent slopes)	168.27	1.68
20B	Elsinboro sandy loam (2 to 7 percent slopes)	106.89	1.07
21B	Fairfax loam (2 to 7 percent slopes)	330.28	3.30
21C	Fairfax loam (7 to 15 percent slopes)	31.03	0.31
23C	Gaila sandy loam (7 to 15 percent slopes)	142.50	1.42
23D	Gaila sandy loam (15 to 25 percent slopes)	390.54	3.90
23E	Gaila sandy loam (25 to 50 percent slopes)	170.10	1.70
24B	Glenelg-Buckhall complex (2 to 7 percent slopes)	115.04	1.15
24C	Glenelg-Buckhall complex (7 to 15 percent slopes)	430.82	4.30
24D	Glenelg-Buckhall complex (15 to 25 percent slopes)	169.55	1.69
25A	Glenville loam (0 to 4 percent slopes)	53.97	0.54
26A	Hatboro silt loam (0 to 2 percent slopes)	2.19	0.02
27A	Hatboro-Codorus complex (0 to 2 percent slopes)	354.54	3.54
29B	Hoadly loam 2 to 7 percent slopes)	82.40	0.82
30B	Jackland silt loam (2 to 7 percent slopes)	3.12	0.03
31C	Jackland-Haymarket complex (7 to 15 percent slopes)	2.36	0.02
34C	Lunt loam (7 to 15 percent slopes)	6.96	0.07
36D	Marr very fine sandy loam (7 to 25 percent slopes)	0.94	0.01

38B	Meadowville loam (0 to 5 percent slopes)	481.21	4.81
39B3	Minnieville clay loam (2 to 7 percent slopes, severely eroded)	86.63	0.87
39C3	Minnieville clay loam (7 to 15 percent slopes, severely eroded)	250.50	2.50
41B	Neabsco loam (0 to 7 percent slopes)	600.44	6.00
41C	Neabsco loam (7 to 15 percent slopes)	229.10	2.29
42B	Neabsco-Quantico complex (2 to 7 percent slopes)	233.29	2.33
44D	Occoquan sandy loam (7 to 25 percent slopes)	83.23	0.83
44E	Occoquan sandy loam (25 to 50 percent slopes)	107.11	1.07
45C	Orenda loam (7 to 15 percent slopes)	39.56	0.40
47B	Quantico sandy loam (2 to 7 percent slopes)	185.31	1.85
47C	Quantico sandy loam (7 to 15 percent slopes)	403.26	4.03
47D	Quantico sandy loam (15 to 25 percent slopes)	132.32	1.32
50D	Spriggs silt loam (15 to 25 percent slopes)	247.05	2.47
50E	Spriggs silt loam (25 to 50 percent slopes)	95.33	0.95
51E	Stumptown very flaggy loam (25 to 50 percent slopes)	56.51	0.56
54B	Urban land-Udorthents complex (0 to 7 percent slopes)	2,687.25	26.84
55D	Watt channery silt loam (15 to 25 percent slopes)	130.72	1.31
55E	Watt channery silt loam (25 to 50 percent slopes)	270.83	2.71
W	Water	14.02	0.14

Climate

The Neabsco Creek watershed lies in the eastern part of Prince William County. In order to obtain climate data for the watershed, the National Climatic Data Center was queried to find the nearest climate monitoring station. While several stations exist in Prince William County (Quantico and Manassas) these stations stopped collecting data in the 70s and 80s. In order to get a more current record of climate, data was obtained from Washington Reagan National Airport (National Airport), located in nearby Arlington County, Virginia. The average annual rainfall as recorded at National Airport (NCDC Station 448906, approximately 19 miles northeast of study area) is 39.8 inches. Table 3 presents a summary of climate data for the National Airport weather station.

Table 3. Climate summary for Washington Reagan National Airport (NCDC Station 448906) from 1/1/1970 – 6/30/2007.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	43.3	47.0	56.1	66.8	75.7	84.1	88.3	86.8	79.8	68.4	58.3	47.8	66.9
Average Min. Temperature (F)	28.3	30.3	37.7	46.7	56.6	65.9	70.5	70.0	62.8	50.7	41.2	32.9	49.5
Average Precipitation (in.)	2.9	2.6	3.5	2.9	3.7	3.6	3.9	3.3	3.7	3.4	3.2	3.1	39.8

Land Use

The Neabsco Creek watershed study area is predominately developed land (51.2 percent). The remaining lands in the impaired watershed consist of forested lands (33.1 percent), pasture/open lands (14.9 percent), and barren lands, wetlands, and open water (0.8 percent) (NLCD, 2001). Table 4 shows the percentage of each land use by category, and Figure 4 shows a map of the distribution of land use in the watershed. It is important to note that the percentages of the different land use categories are based on data from 2001. Since the collection of the 2001 NLCD land use data, substantial residential development has taken place in the Neabsco Creek watershed. (Prince William County Planning Department).

Table 4. Land Use by category in the Neabsco Creek watershed.

Land Use Type	Total Acres in Watershed	Percent of Total Watershed
Developed Lands**	5,126	51.2
Wetlands	25	0.2
Forested	3,308	33.1
Pasture/Open Lands	1,492	14.9
Open Water	7	0.1
Barren land	51	0.5
Total:	10,009	100.0

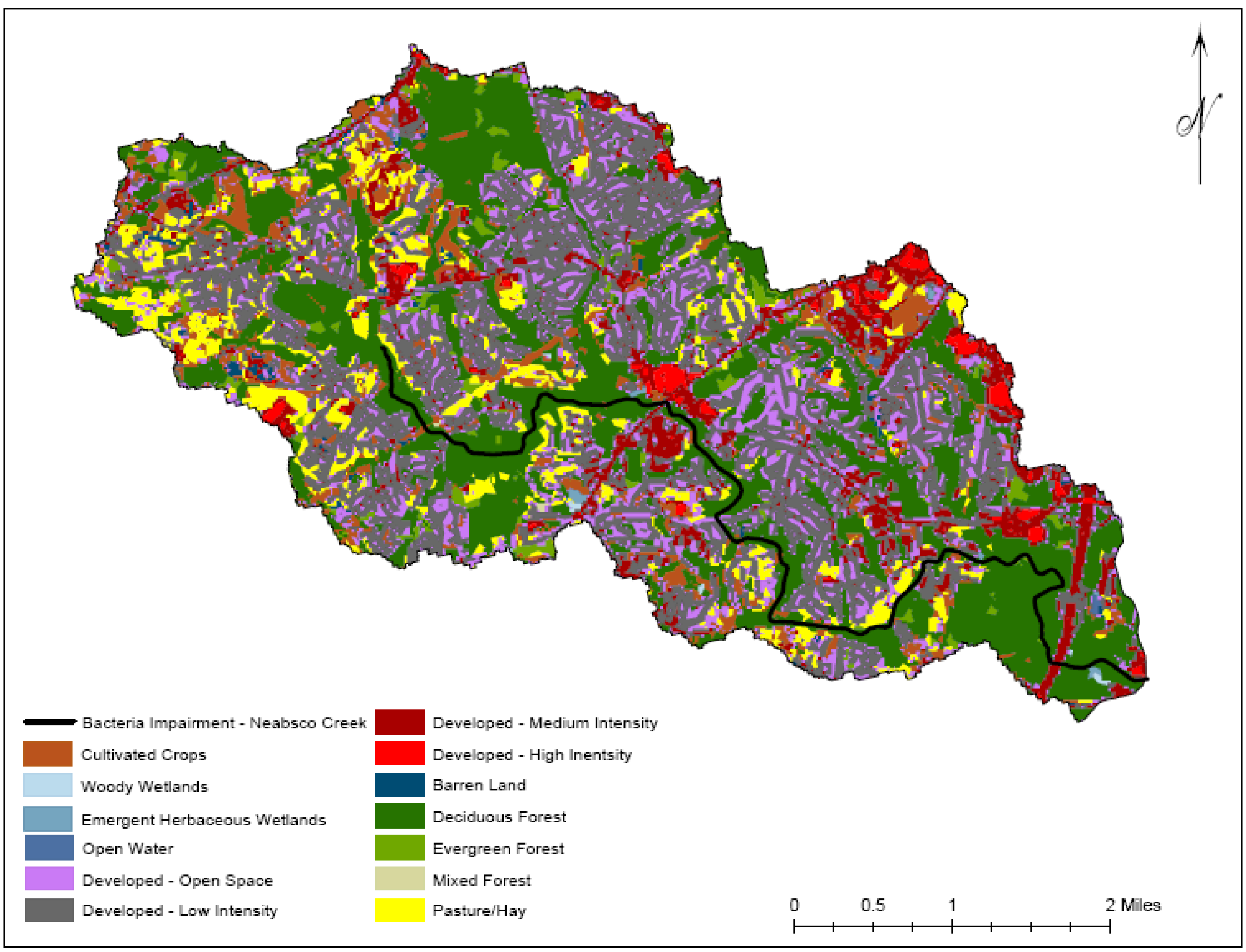

Figure 4. Land use in the Neabsco Creek watershed.

3. Description of Water Quality Problem/Impairment

Neabsco Creek was listed as impaired in Virginia's 2002 303(d) Report on Impaired Waters, the 2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report, and the 2006 305(b)/303(d) Water Quality Assessment Integrated Report (VADEQ, 2002, 2004, and 2006) for not supporting the recreation use due to exceedances of the State's water quality standard for fecal coliform bacteria. The main sampling station on Neabsco Creek is located at the Route 1 Bridge crossing (Station 1ANEA002.89). Out of 23 samples collected at Station 1ANEA002.89 during the 2002 assessment period, five (22%) exceeded the water quality criterion for fecal coliform at station 1ANEA002.89. Seven of 23 samples (30%) exceeded the fecal coliform bacteria water quality criterion during the 2004 water quality assessment period, and five of 17 samples (29%) exceeded the criterion during the 2006 assessment period. This impaired segment of Neabsco Creek is listed in Attachment C (Plaintiff's list of waters that were added to the 303(d) list in 2002) of the 1999 Consent Decree (*American Canoe Association, Inc. and American Littoral Society vs. United States Environmental Protection Agency, et. al*, 1999) for fecal coliform.

The complete DEQ sampling record for bacteria in Neabsco Creek is presented in Table 5. Table 6 shows the summary of data collected for Neabsco Creek that was used in the 2006 Integrated 305(b)/303(d) Report. The locations of the Neabsco Creek sampling station are found in Figure 5.

Table 5. Fecal Coliform and *E. coli* sampling record for DEQ monitoring stations on Neabsco Creek.

Station	Date of First Sample	Date of Last Sample	Fecal Coliform*				*E. coli***			
			Minimum cfu/100mL	Maximum cfu/100mL	Average cfu/100mL	Exceedance Rate	Minimum cfu/100mL	Maximum cfu/100mL	Average cfu/100mL	Exceedance Rate
1ANEA002.89 (Route 1)	9/12/1974	6/19/2007	18	8000	508	24 out of 171 (14%)	4	320	118	2 out of 15 (13%)
1ANEA005.06 (Downstream from Dale Service 1)	1/24/1971	7/31/1974	100	6000	954	5 of 28 (18%)	NA	NA	NA	NA
1ANEA005.15 (Upstream from Dale Service 1)	1/24/1972	7/31/1974	100	2800	262	4 of 29 (14%)	NA	NA	NA	NA
1ANEA009.12 (Route 640)	9/12/1974	6/18/1979	3	1000	131	3 of 46 (7%)	NA	NA	NA	NA
1ANEA009.35 (Route 610)	1/23/1975	6/21/2006	50	1700	300	6 of 20 (30%)	50	1400	325	6 of 12 (50%)
1ANEA012.33 (Princedale Drive)	1/23/1975	8/11/1977	100	100	100	0 of 3 (0%)	NA	NA	NA	NA

Table 6. Fecal Coliform sampling data used in the 2006 Integrated 305(b)/303(d) Report (1/1/2000 to 12/31/2004).

Station	Date of First Sample	Date of Last Sample	Fecal Coliform*				*E. coli***			
			Minimum cfu/100mL	Maximum cfu/100mL	Average cfu/100mL	Exceedance Rate***	Minimum cfu/100mL	Maximum cfu/100mL	Average cfu/100mL	Exceedance Rate
1ANEA002.89 (Route 1)	11/28/2000	06/10/2003	100	1500	342	4 of 12 (33%)	NA	NA	NA	NA

* The exceedance rate for fecal coliform was obtained by comparing the sample value with the interim fecal coliform instantaneous standard of 400 cfu/100mL.
** The exceedance rate for *E. coli* was obtained by comparing the sample value with the *E. coli* instantaneous standard of 235 cfu/100mL.
*** The exceedance rate recorded here differs from what was recorded in the 2006 Integrated Assessment Report. This is due to quality control issues that were addressed after the publication of the Final 2006 Report. The exceedance rate recording in the 2006 305(b) report was 5 of 17 samples (29.4%). In both instances, there are enough exceedances of the Fecal Coliform water quality standard to list the water body as impaired.

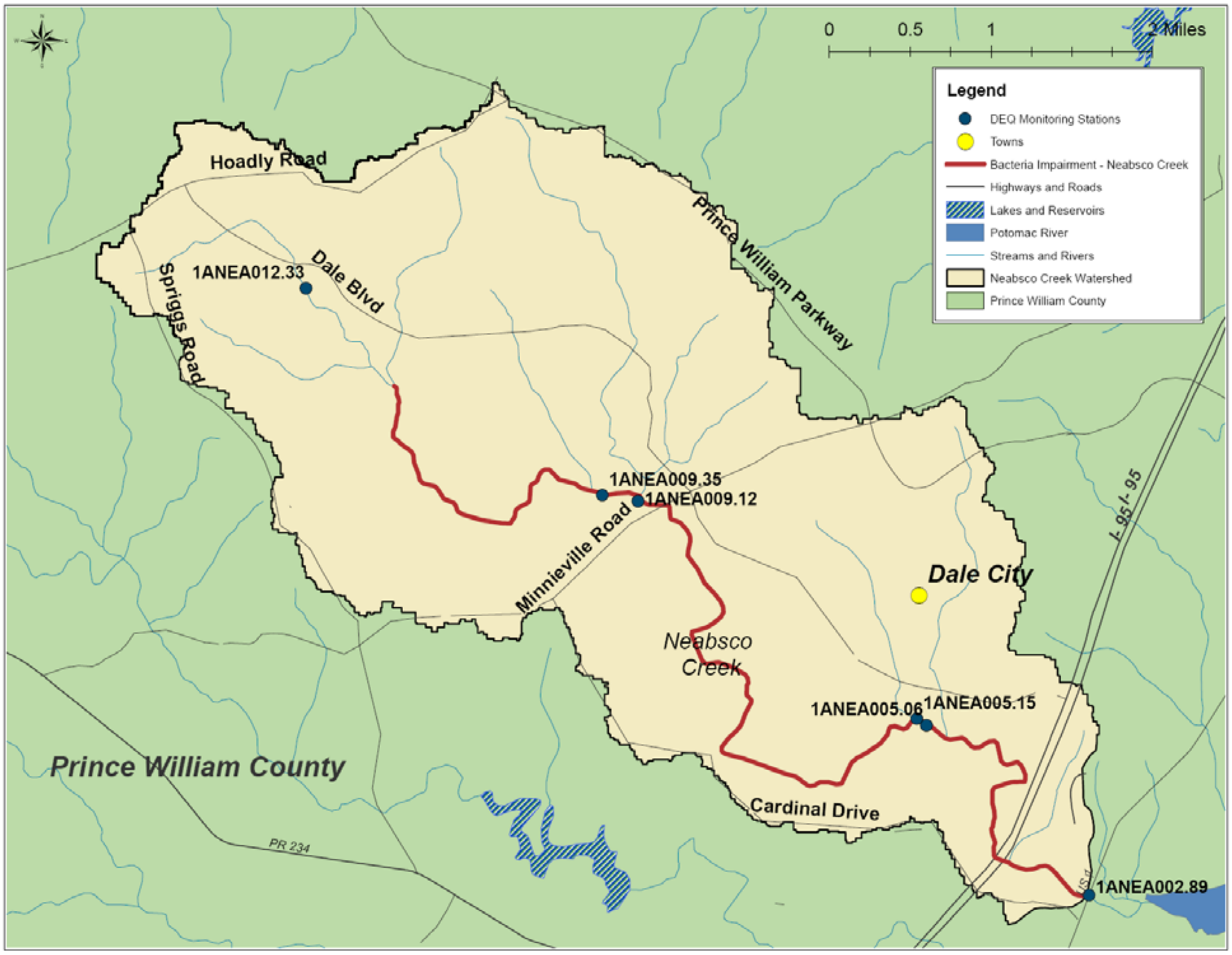

Figure 5. Map of DEQ monitoring stations in the Neabsco Creek watershed.

From 1974 to 2005 DEQ tested for Fecal Coliform bacteria in the water quality samples taken at Neabsco Creek. During 2005, DEQ began to test for *E. coli* bacteria in the samples. For the purposes of this TMDL study, a translator equation was applied to the Fecal Coliform data to translate it into terms of *E. coli.* The translator equation provides an estimate of what the Fecal Coliform concentration would be in terms of an *E. coli* concentration. This is useful in viewing all the bacteria data as *E. coli*. The Fecal Coliform to *E. coli* translator equation is as follows:

$$\log2\,(EC) = -0.0172 + 0.91905 * \log2\,(FC) \qquad \text{(Equation 1)}$$

Where: EC = *E. coli* concentration (cfu/100mL)
FC = fecal coliform concentration (cfu/100mL)

The translator equation was developed from paired measurements of *E. coli* and Fecal Coliform bacteria. Documentation of the translator equation can be found in Appendix G. A time series graph of the data that DEQ collected at the impairment listing station, 1ANEA002.89, from 1974 until present is shown in Figure 6. The orange line at 235 cfu/100 mL represents the instantaneous *E. coli* water quality criterion. The data points above the 235 cfu/100 mL line illustrate exceedances of the water quality criterion. Data points in blue represent fecal coliform bacteria concentrations that were translated into *E. coli* concentrations, and data points in orange represent measured *E. coli* bacteria concentrations. Figure 7 presents the distribution of water samples and exceedances (instantaneous *E coli* water quality criterion - 235 cfu/100mL) by month for the impairment listing station 1ANEA002.89.

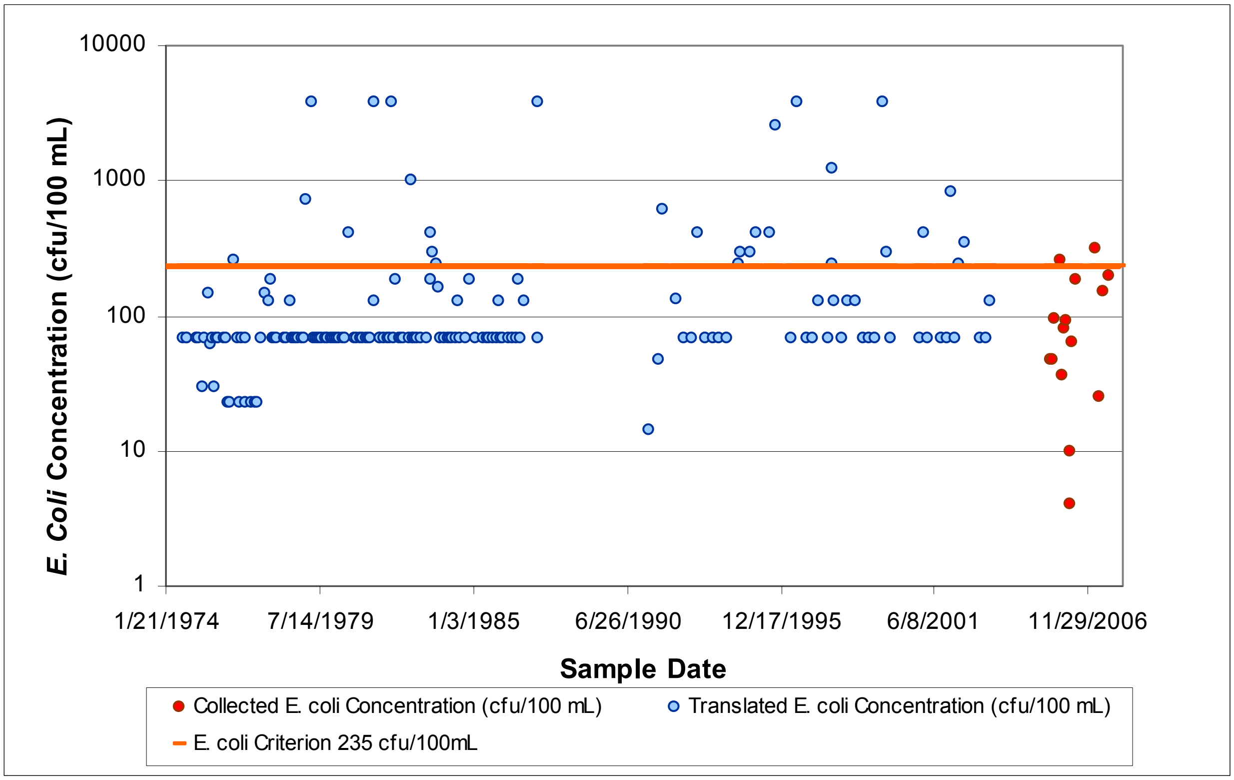

Figure 6. Time series of *E. coli* concentrations at Station 1ANEA002.89 from 1974 to present.

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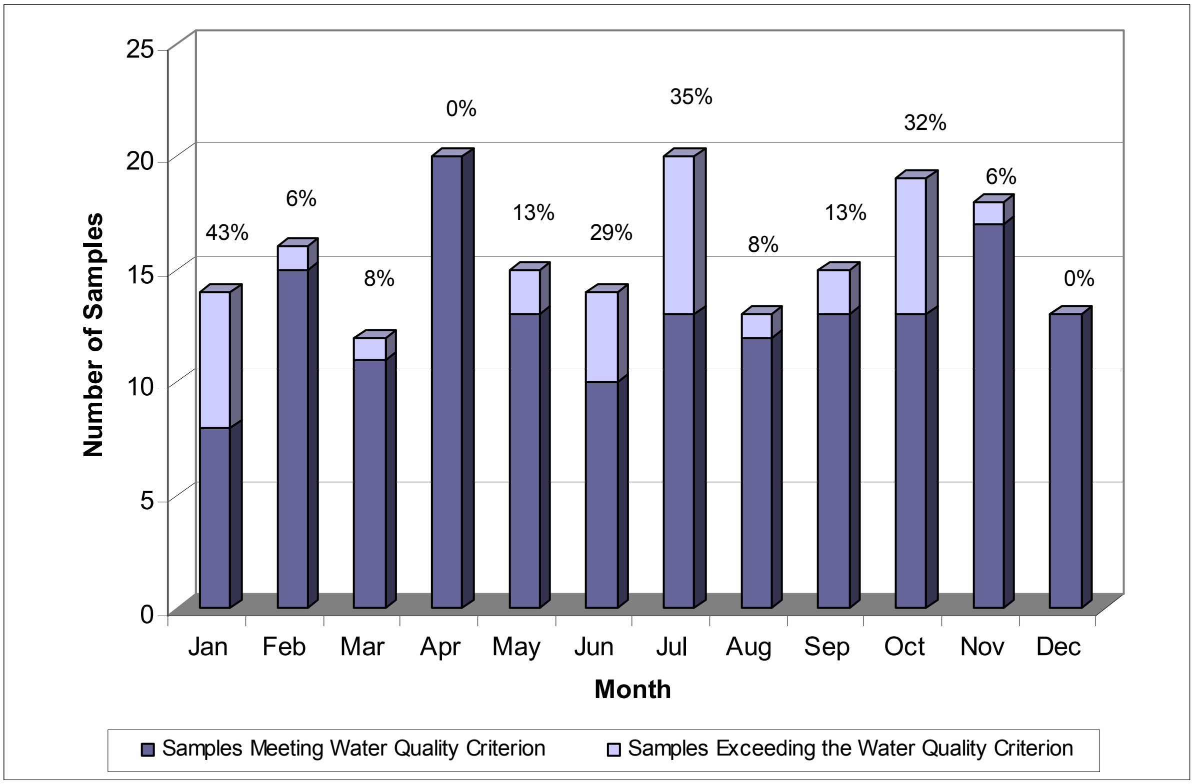

Figure 7. Seasonal distribution of *E. coli* samples and percent exceedances of the instantaneous Criterion (Station 1ANEA002.89).

4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria that are designed to protect the uses. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

As stated above, Neabsco Creek must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for bacteria in the Neabsco Creek watershed have changed since the initial listing on the 303(d) report. Following EPA recommendations, the Virginia Department of Environmental Quality (DEQ) proposed more stringent fecal coliform bacteria standards as well as new standards for *E. coli* bacteria. These new standards were adopted by the State Water Control Board in May 2002, public noticed in June 2002, approved by the USEPA in November 2002, and made effective January 15, 2003.

The EPA recommendation that states adopt *E. coli* and enterococci (saltwater) standards stems from a stronger correlation between the concentration of *E. coli* and enterococci organisms and the incidence of gastrointestinal illness. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals.

Bacteria Standards

For a non-shellfish supporting water body such as Neabsco Creek to be in compliance with Virginia bacteria standards for primary contact recreational use, the Virginia Water Quality Standards specify the following criteria (9 VAC 25-260-170):

1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:

Table 7. Applicable water quality standards.

Parameter	Geometric Mean[1] (cfu/100 ml)	Single Sample (cfu/100 ml)
E. coli (freshwater)	126	235
Enterococci (saltwater and Transition Zone 3)	35	104

[1] For two or more samples taken during a calendar month.

Although Neabsco Creek was listed as impaired due to exceedances of the previous fecal coliform standard, the TMDL must be developed to meet the new *E. coli* bacteria standard.

If a water body exceeds the above criteria more than 10% of the time, the water body is classified as impaired and the development and implementation of a TMDL is required. If the sampling frequency was one sample or less per 30 days, the instantaneous criterion was applied; for a higher sampling frequency, the geometric mean criterion was applied. Sufficient fecal coliform bacteria standard exceedances were recorded at VADEQ water quality monitoring station 1ANEA002.89 in the 2002, 2004, and 2006 assessments to indicate that the recreational use designation is not being supported.

For Neabsco Creek, the TMDL is required to meet the instantaneous criterion since the load-duration approach used to develop the TMDL for Neabsco Creek yields the maximum allowable bacteria concentration under any given flow condition. Unlike a continuous time series simulation, the flow-duration approach does not yield daily bacteria concentrations which are needed to apply the geometric mean standard. Such an approach ensures that TMDLs, when implemented, do not result in exceedances over a wide variety of scenarios that affect bacteria loading.

5. Assessment of Bacteria Sources

The assessment of bacteria sources in bacteria TMDL studies using hydrologic computer models involves estimating loads from sources in the watershed and developing a model to establish the links between estimated loads and actual in-stream bacteria concentrations.

In a load-duration bacteria TMDL, source assessment is accomplished by determining the relative contribution by source of the fecal bacteria contained in a sample of stream water. This method of source identification is achieved through microbial source tracking (MST). MST methods that specifically use bacteria as the target organism are referred to collectively as bacteria source tracking (BST) methods. MST has been applied to study microbial ecology of environmental systems for years and is now being applied to help improve water quality by identifying problem sources and determining the effect of implemented remedial solutions. Management and remediation of water pollution is more cost effective if the correct sources of pollution are identified (Carter Run TMDL, 2005).

To support BST analyses in load-duration TMDLs, the bacteria loading in a watershed is also estimated. These load estimates are broken into point and non-point sources. It is important to note that the non-point source load estimates represent loading to the land surface of the watershed; they are not estimates of in-stream loads.

The following sections present BST analysis and point and non-point source load estimates.

5.1. Bacteria Source Tracking (BST)

5.1.1. Background

MST methods can be divided into three categories: molecular (genotype), biochemical (phenotype), and chemical. Molecular methods may offer the most precise identification of specific types of sources but are limited by high per-isolate costs and detailed and time-consuming procedures. They are not yet suitable for assaying large numbers of samples in a reasonable time frame. Biochemical methods (BST) may or may not be as precise, but are simpler, quicker, less costly, and allow large numbers of samples to be assayed in a short period of time (Carter Run TMDL, 2005).

Several biochemical BST methods are in various stages of development. Among these are Antibiotic Resistance Analysis (ARA), F-Specific (F+ or FRNA) Coliphage, Sterols or Fatty Acid Analysis, Nutritional Patterns, and Fecal Bacteria Ratios. Of these, ARA has been chosen as the BST method for this TMDL study.

The ARA method uses fecal streptococcus (including the enterococci) and/or *E. coli* and patterns of antibiotic resistance for separation of sources. The premise is that human fecal bacteria will have the greatest resistance to antibiotics and that domestic and wildlife animal fecal bacteria will have significantly less resistance (but still different) to the battery of antibiotics and concentrations used. Most investigators are testing each isolate on 30 to 70+ antibiotic concentrations (Carter Run 2005). A more detailed description of the ARA method used by MapTech, Inc. in support of this TMDL is presented in Appendix B.

5.1.2. BST Sampling and Results

A total of 12 ambient water quality samples were collected by DEQ staff at Station 1ANEA002.89 between July 2005 and June 2006. These data were submitted to the Environmental Diagnostics Laboratory of MapTech, Inc. (MapTech) for BST analysis. The BST analyses performed by MapTech determined the relative contribution of overall bacteria by human, pet, livestock, and wildlife sources. Fecal Coliform and *E. coli* bacteria were also enumerated as part of the analyses performed by MapTech.

Prince William County also collected 13 BST samples from Neabsco Creek near the DEQ Station 1ANEA002.89. These samples were collected from July 2003 to June 2004, and included a storm flow sample. Prince William County's BST sampling and analysis were performed by Dr. Charles Hagedorn's lab in conjunction with the Virginia Tech Microbial Source Tracking Program. One difference in the BST data collected by DEQ versus the BST data collected by Prince William County is that while the DEQ analysis (performed by MapTech, Inc.) separated results into 4 categories (human, livestock, pet, and wildlife), the Prince William County analysis (performed by Dr. Hagedorn's lab) reported results in five categories (human, livestock, pet, wildlife, and waterfowl). In order to better compare the data, Prince William County's waterfowl and wildlife categories were combined under the heading of wildlife. Results of the Neabsco Creek BST sampling program at Station 1ANEA002.89 are presented in Tables 8 and 9.

Table 8. BST sampling data for Neabsco Creek at Station 1ANEA002.89.

Collector ID	Sample Date	Flow (cfs)	*Number of Isolates*	*E. coli* (cfu/100mL)	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC[1]	7/9/2003	113.9	24	2607	82%	0%	0%	18%
PWC	8/6/2003	6.5	24	260	78%	0%	0%	22%
PWC	9/5/2003	11.1	24	400	72%	0%	0%	28%
PWC	10/9/2003	5.7	24	140	70%	0%	0%	30%
PWC	11/5/2003	78.1	24	70	82%	0%	0%	18%
PWC	11/7/2003	48.2	24	1270	78%	0%	0%	22%
PWC	12/3/2003	10.4	24	30	82%	0%	0%	18%
PWC	1/7/2004	11.1	24	40	96%	0%	0%	4%
PWC	2/4/2004	37.1	24	95	96%	0%	0%	4%
PWC	3/2/2004	20.2	24	90	96%	0%	0%	4%
PWC	4/6/2004	11.7	24	235	79%	0%	0%	21%
PWC	5/5/2004	11.1	24	5680	71%	0%	0%	29%
PWC	6/2/2004	9.1	24	800	69%	0%	0%	31%
DEQ[2]	7/20/2005	6.3	24	96	63%	0%	4%	33%
DEQ	8/24/2005	2.3	9	48	22%	0%	11%	67%
DEQ	9/27/2005	3.8	23	96	39%	9%	17%	35%
DEQ	10/26/2005	29.3	24	254	42%	4%	42%	12%
DEQ	11/29/2005	9.1	24	36	55%	33%	12%	0%
DEQ	12/21/2005	7.8	24	80	17%	25%	50%	8%
DEQ	1/24/2006	20.2	24	92	29%	0%	38%	33%
DEQ	2/21/2006	10.4	1	4	0%	0%	100%	0%
DEQ	3/28/2006	4.8	5	10	60%	0%	40%	0%
DEQ	4/19/2006	5.8	22	64	36%	5%	45%	14%
DEQ	5/9/2006	5.2	23	186	44%	9%	30%	17%
DEQ	6/21/2006	4.0	24	320	33%	4%	55%	8%

[1] Prince William County
[2] Virginia Department of Environmental Quality

The annual BST percentages for wildlife, human, livestock and pet were weighted by the number of isolates, *E. coli* concentration, and flow, in order to give more significance to sampling events that showed higher *E. coli* concentrations. Table 9 shows the final weighted BST percentage calculations.

Table 9. Weighted percentage calculations for BST data.

		Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)				***Annual Weighted Averages (Sum by Category and Divide by Total)***			
Collector ID	**Sample Date**	**BST Distribution**				**BST Distribution**			
		Wildlife	**Human**	**Livestock**	**Pet**	**Wildlife**	**Human**	**Livestock**	**Pet**
PWC[1]	7/9/2003	5,843,860	0	0	1,282,799	79%	0%	1%	20%
PWC	8/6/2003	31,679	0	0	8,935				
PWC	9/5/2003	76,480	0	0	29,742				
PWC	10/9/2003	13,318	0	0	5,708				
PWC	11/5/2003	107,597	0	0	23,619				
PWC	11/7/2003	1,145,926	0	0	323,210				
PWC	12/3/2003	6,148	0	0	1,350				
PWC	1/7/2004	10,197	0	0	425				
PWC	2/4/2004	81,204	0	0	3,383				
PWC	3/2/2004	41,839	0	0	1,743				
PWC	4/6/2004	52,200	0	0	13,876				
PWC	5/5/2004	1,070,934	0	0	437,424				
PWC	6/2/2004	120,719	0	0	54,236				
DEQ[2]	7/20/2005	9,164	0	582	4,800				
DEQ	8/24/2005	217	0	108	659				
DEQ	9/27/2005	3,307	763	1,441	2,968				
DEQ	10/26/2005	74,990	7,142	74,990	21,426				
DEQ	11/29/2005	4,330	2,598	945	0				
DEQ	12/21/2005	2,546	3,744	7,488	1,198				
DEQ	1/24/2006	12,935	0	16,949	14,718				
DEQ	2/21/2006	0	0	42	0				
DEQ	3/28/2006	144	0	96	0				
DEQ	4/19/2006	2,940	408	3,675	1,143				
DEQ	5/9/2006	9,788	2,002	6,674	3,782				
DEQ	6/21/2006	10,138	1,229	16,896	2,458				

[1]PWC (Prince William County)
[2]DEQ (Virginia Department of Environmental Quality)

The BST data results indicate that the majority of bacteria present at Station 1ANEA002.89 are from wildlife populations in the watershed (79%). The remainder of the bacteria are from pet sources (20%) and a small portion (1%) from livestock. There was also an insignificant (less than 1%) human signal present in the BST results. Prince William County also collected BST samples at five other upstream locations along Neabsco Creek and its tributaries. The BST results from these upstream stations showed similar distributions among sources. The location of the upstream BST sampling stations, along with the results from this additional BST monitoring are presented in Appendix F.

5.2. Point Sources

5.2.1. Individual Virginia Pollutant Discharge Elimination System (VPDES) Permits

Bacteria loading from point sources such as sewage treatment plants, small commercial establishments, schools, homes and businesses require permits under the Virginia Pollutant Discharge Elimination System (VPDES) permit program. Two bacteria point source dischargers were identified in the Neabsco

Creek watershed. Both are covered under an individual VPDES permit. The permitted point sources are presented in Table 10.

Table 10. VPDES point source facilities and loads.

VPDES Permit Number	Facility Name	Receiving Stream	Watershed ID	Design Flow (MGD)[1]	Effluent Limit (cfu/100mL)	Waste Load Allocation (cfu/day)
VA0024724	Dale Service Corporation Section 1	Unnamed Tributary to Neabsco Creek	VAN-A25R	4.6	126	2.19×10^{10}
VA0024678	Dale Service Corporation Section 8	Neabsco Creek	VAN-A25R	4.6	126	2.19×10^{10}
			Existing WLA	9.2	126	4.39×10^{10}
Expansion Matrix[2]						
					Total x 2	8.78×10^{10}
					Total x 5	2.20×10^{11}

[1]This is the maximum permitted design flow for the facility.
[2]The five-times load (2.20×10^{11}) will be the VPDES permit portion of the WLA. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but the growth-expanded allocation will be allocated to both new and existing permits as determined by the VADEQ VPDES program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.

The bacteria loads for the VPDES permits were calculated by multiplying the permitted discharge concentration (126 cfu/100mL) by the maximum permitted design flow and the appropriate unit conversions. Future growth and expansion in the watershed were incorporated into the load for the sewage treatment plants by including a growth factor equivalent to five-times the maximum permitted design flow of the permitted facilities.

5.2.2. Municipal Separate Storm Sewer System (MS4) Permits

Four Municipal Separate Storm Sewer System (MS4) permits have been issued to localities within the Neabsco Creek impaired watershed (Table 11). Prince William County holds a Phase I MS4 Stormwater permit, while Prince William County Schools, the Woodbridge Campus of Northern Virginia Community College, and the Virginia Department of Transportation all hold Phase II MS4 Stormwater permits.

In order to determine the waste load allocation for the MS4 permitted entities, it was first necessary to separate out the bacteria loadings attributed to the MS4 entities versus bacteria loadings attributed to other land-based, non-point sources. Although the entire Neabsco Creek watershed lies within the geographical bounds of the Prince William County Phase I permit area, forested corridors along Neabsco Creek and its tributaries are not realistically able to be controlled by storm water control measures implemented by the county, or other MS4 permit holders in the watershed. Therefore, all urbanized, developed land within the watershed was classified as an MS4 area and the land based load corresponding to that urban area was included in the waste load allocation (WLA). The load from the remaining forested lands was categorized as the load allocation (LA) and took into account the natural/background levels of bacteria present in the forested stream corridors along Neabsco Creek and its tributaries. The urbanized area was determined by using the 2001 National Land Cover Data (NLCD) land cover layer of the watershed. Figure 8 shows the estimated urbanized/developed land area in the Neabsco Creek watershed that is attributed to MS4 permits. The load from the MS4 areas accounts for approximately 78% of the watershed, and is included in the WLA. The load from the remaining 22% is counted under the non-point source LA.

Due to the spatial overlap between the MS4 entities and the resulting uncertainty of the appropriate operator of the system, the loads from MS4 permitted entities are aggregated in the TMDL. For instance, certain roads within a county are maintained by VDOT, some by the county, and some by private subdivisions. Thus, it was not practical to separate out individual allocations to each MS4 permit holder. Rather, one single waste load allocation was given to the MS4 permit holders in the watershed. Table 11 lists the MS4 permit holders in the Neabsco Creek watershed.

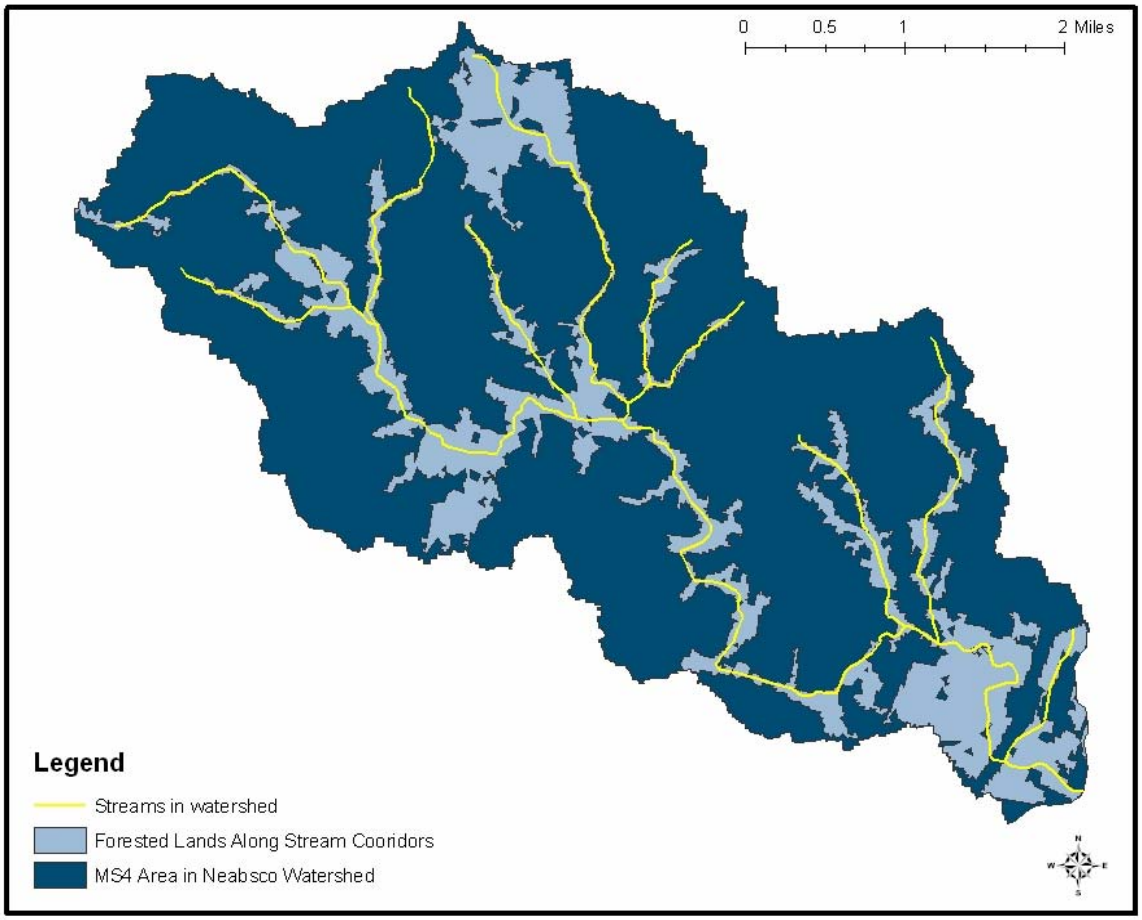

Figure 8 - Areas covered by the MS4 permits in the Neabsco Creek watershed.

Table 11 - MS4 permits in the Neabsco Creek watershed.

Permit Number	MS4 Permit Holder	WLA (cfu/day)[1]
VA0088595	Prince William County	1.05×10^{12}
VAR040100	Prince William County Public Schools	
VAR040062	VDOT – Northern Urban Area	
VAR040095	Northern Virginia Community College	

[1]See Section 6.2 for further explanation of how the WLA for MS4 areas was determined.

5.3. Non-Point Sources

In order to gain an understanding of non-point source loading in the Neabsco Creek watershed, bacteria loads for typical non-point sources were estimated. These estimates were based upon animal and human population data sets, typical waste production rates, and typical bacteria densities in waste products.

Currently published values for fecal bacteria production rates are primarily in terms of fecal coliform. Studies have shown that though minor variability will exist between sources, *E. coli* represents roughly 90-95% of fecal coliforms contained in "as-excreted" fecal material (Carter Run TMDL, 2005). This implies that the relative bacteria contribution by source should remain constant.

It is important to note that the bacteria loads presented in the following sections on non-point sources represent "as-produced" loads. Portions of an estimated load may not be available to be transported to Neabsco Creek in runoff.

5.3.1. Humans and Pets

Bacteria loading from human sources can come from straight pipes, failing septic systems, and land-applied biosolids. Failing septic systems are typically manifested by effluent discharging to the ground surface where the bacteria laden effluent is then available to be washed into a stream as runoff during a precipitation event. In contrast, discharges from straight pipes are typically directly deposited to streams.

All biosolids can contain a certain concentration of fecal bacteria. When biosolids are applied to the land surface, the potential exists for a portion of these fecal bacteria to be transported to a stream as runoff during storm events.

Straight Pipes

There are no known straight pipes in the Neabsco Creek Watershed. An estimate of the potential number of straight pipes in the watershed was made using best professional judgment (Meehan, 2007).

Septic Systems

It is estimated that there are approximately 175 homes in the Neabsco Creek watershed that are on septic systems. The remaining homes are on a public sewer system. The Prince William County Health Department indicated that the majority of homes on septic systems were not located near Neabsco Creek or its tributaries, and none were estimated to be within 200 feet of the impaired stream. The geology and landforms in the Neabsco Creek watershed are such that the soils that allow a septic system are located on a side-slope or ridge well away from streams. (Meehan, 2007).

Biosolids

The Prince William County Department of Health indicated that no biosolids have been spread in the Neabsco Creek watershed since the 1970s (Meehan, 2007).

Pets

The number of pets in the watershed was estimated based on the number of households. The estimated number of households in the Neabsco Creek watershed in 2006 is 45,995 (United States Census, 2002). Assuming an average of 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association, 2007) the estimated pet population in the Neabsco Creek watershed consists of 26,677 dogs and 30,357 cats.

Table 12. Estimated daily fecal coliform production from pets in the Neabsco Creek watershed.

Source	Population	Waste Production Rate/day (grams/day/animal)*	Waste Fecal Coliform Density*	Total Estimated Daily Fecal Coliform Production (cfu/day)
Dogs	26,677	450 grams/day/dog	4.8×10^5 cfu/g	5.76×10^{12}
Cats	30,357	19.4 grams/day/cat	9 cfu/g	5.30×10^6
			Total:	***5.76 x 10^{12}***

* Carter Run TMDL Report, 2005.

5.3.2. Livestock

Fecal matter from livestock can be deposited directly to the stream in instances where livestock have stream access, or the fecal matter can be transported to the stream in surface runoff from grazing or pasture lands.

There is a very small livestock population in the Neabsco Creek watershed. Conservative estimates of the current livestock population in the watershed were derived using the 2002 United States Department of Agriculture National Agriculture Statistics Service Census of Agriculture data for Prince William County (http://www.nass.usda.gov/census/census02/profiles/va/cp51153.PDF) and input from local stakeholders. The Neabsco Creek watershed is located entirely within Prince William County and contains approximately 44 acres of the total pasture land in the county, as determined by GIS analysis (Prince William County Planning Office – Land Use Layer 2007). The estimated number of each type of livestock in the Neabsco Creek watershed was determined using a ratio between the numbers of livestock on pastured land in Prince William County, and the amount of pasture land in the Neabsco Creek drainage. The following is an example of how the number of layers (chickens) was determined:

$$\frac{Layers\ in\ PWC}{Acres\ of\ \ Pasture\ Land\ in\ PWC} = \frac{Layers\ in\ Neabsco}{Acres\ of\ \ Pasture\ Land\ in\ Neabsco} \qquad \text{(Equation 2)}$$

$$\frac{1{,}588\ Layers}{27{,}939\ acres} = \frac{X}{44\ acres}$$

$$X = 1\ Layer$$

Where:

PWC = Prince William County
Neabsco = Impaired portion of the Neabsco Creek watershed
X = Number of estimated Layers (Chickens) in the Neabsco Creek watershed

This conservative approach was used for all categories of livestock except horses and cattle. Information provided by the Technical Advisory Committee (TAC) for the project indicated that a horse farm was located in the northwest portion of the watershed, with an estimated count of ten horses located on the property. This too is a conservative estimate since part of the pasture land on the farm lies in a neighboring watershed. It should also be noted that the numbers presented in Table 13 represent loads available for runoff and **not** in-stream loads.

Table 13. Estimated daily fecal coliform production from livestock in the Neabsco Creek watershed.

Source	Population		Waste Production Rate (lbs/animal/day)[2]	Fecal Density (cfu/g)[2]	Total Fecal Production (cfu/day)
	Prince William County	Neabsco Creek Watershed[1]			
Beef Cows	2,321	1	46.4	1.01×10^5	1.41×10^{10}
Dairy Cows	1,325	1	120.4	2.58×10^5	3.11×10^7
Hogs and Pigs	27	0	11.3	4.00×10^5	0
Sheep and Lambs	1,650	0	2.4	4.30×10^4	0
Layers	1,588	1	1.40×10^8 (cfu/animal/day)		1.4×10^8
Broilers	0	0	1.40×10^8 (cfu/animal/day)		0
Horses	1422	10	51.0	9.40×10^4	2.17×10^{10}
				Total:	***3.60×10^{10}***

[1]For the purpose of determining the livestock numbers in the Neabsco Creek watershed, the Prince William County Planning Department provided a 2007 land use GIS layer. The categories of land use in the Prince William County (PWC) GIS layer were different than the main land cover layer used for this project (NLCD). The differences arise in that the PWC layer is intended for planning purposes, and lists the use of each land parcel (i.e. restaurant, single family home, school), whereas the NLCD layer provides information on what coverage is on the ground, irregardless of purpose. For example, a parcel of land in the PWC GIS might list the land as being owned by a school, however, the NLCD dataset would show how much of that parcel of land is developed, grassy recreational area, or forested. While the Prince William County GIS layer could not be used for determining overall land cover information for the watershed, it did provide useful insight into the available agricultural lands in the watershed. One of the specific land use categories in the PWC GIS layer was agricultural, and because the PWC layer was more up-to-date than the NLCD dataset, this information was used to determine the total acres of agricultural land in the watershed.
[2]Carter Run TMDL Report, 2005.

5.3.3. Wildlife

Like livestock, wildlife can also deposit fecal matter either directly into a stream, or indirectly through loads on pastureland, cropland, forested, or residential land. These indirectly depositing loads reach the stream through storm water runoff events. Direct deposition to streams can vary with species. For instance, beavers spend most of their time in water; therefore most of their fecal matter is directly deposited to the stream.

Wildlife populations in the Neabsco Creek watershed were estimated based on wildlife densities obtained from the Virginia Department of Game and Inland Fisheries (DGIF), the Goose Creek Bacteria TMDL (VA DEQ 2003) and the Accotink Creek TMDL (VA DEQ 2002). The wildlife densities used in this project are found in Table 14.

Table 14. Estimated wildlife population densities in the Neabsco Creek watershed.

Animal	Habitat
Deer[1]	0.084/acre of the following habitats: Forest Cropland Pasture/Open Space Low Intensity Development
Raccoon[2]	Low Density Areas (Upland Forests): 10/square mile High Density Areas (bottomland forest, marsh, swamp, along streams with a 600 ft buffer around these areas): 50/square mile
Muskrats[2]	8/mile of medium sized stream intersecting pasture fields 10/mile of pond or lake edge
Beaver[2]	2/mile of permanent streams and rivers 3.8/mile for pond and lake shores
Turkey[3]	Forest: Assume that the gobbler harvest is 10% of the total turkey population on forested lands. Prince William County gobbler harvest in 2006 was .2/square mile of habitat
Duck[4]	High Density: Urban, residential, grass/pasture lands, wetlands within 300 feet of stream corridor: Summer: 0.23/acre Winter: 0.366/acre Low Density: Forested within 300 feet of stream corridor Summer: 0.06/acre Winter: 0.078/acre
Goose[4]	Low intensity urban, residential, grass/pasture lands, wetlands within 300 feet of stream corridor: Summer: 2.34/acre Winter: 2.5/acre

[1] Goose Creek Bacteria TMDL
[2] Mike Fies, Virginia Department of Game and Inland Fisheries, personal communication, 2007
[3] Gary Norman, Virginia Department of Game and Inland Fisheries, personal communication, 2007
[4] Accotink Creek TMDL, 2002

Table 15. Estimated fecal coliform production from wildlife in the Neabsco Creek watershed.

<table>
<tr><th>Source</th><th>Population Density</th><th>Habitat</th><th>Watershed Population (animals)</th><th colspan="2">Range of Waste Production Rate (cfu/animal/day)*</th><th colspan="2">Range of Fecal Coliform Production (cfu/day)</th></tr>
<tr><td>Deer</td><td>0.084/acre</td><td>9,024 acres</td><td>758</td><td colspan="2">3.47×10^{8}</td><td colspan="2">2.63×10^{11}</td></tr>
<tr><td rowspan="2">Raccoon</td><td>High Density 50/mile^2</td><td>11.9 mile^2</td><td>595</td><td colspan="2" rowspan="2">1.13×10^{8}</td><td colspan="2">6.72×10^{10}</td></tr>
<tr><td>Low Density 10/mile^2</td><td>3.7 mile^2</td><td>37</td><td colspan="2">4.18×10^{9}</td></tr>
<tr><td colspan="6" align="right">Total for Raccoons:</td><td colspan="2">7.14×10^{10}</td></tr>
<tr><td rowspan="2">Muskrat</td><td>8/mile of streams</td><td>8.42 miles</td><td>67</td><td colspan="2" rowspan="2">2.50×10^{7}</td><td colspan="2">1.68×10^{9}</td></tr>
<tr><td>10/mile of ponds/lakes</td><td>0.9 miles</td><td>9</td><td colspan="2">2.25×10^{8}</td></tr>
<tr><td colspan="6" align="right">Total for Muskrats:</td><td colspan="2">1.91×10^{9}</td></tr>
<tr><td rowspan="2">Beaver</td><td>2/mile of streams</td><td>8.42 miles</td><td>17</td><td colspan="2" rowspan="2">3.00×10^{5}</td><td colspan="2">5.10×10^{6}</td></tr>
<tr><td>3.8/mile of ponds/lakes</td><td>0.9 miles</td><td>3</td><td colspan="2">9.00×10^{5}</td></tr>
<tr><td colspan="6" align="right">Total for Beavers:</td><td colspan="2">6.00×10^{6}</td></tr>
<tr><td>Turkey</td><td>2/mile^2</td><td>5.1 mile^2</td><td>10</td><td colspan="2">9.30×10^{7}</td><td colspan="2">9.30×10^{8}</td></tr>
<tr><td rowspan="2">Duck (Summer)</td><td>High Density .23/acre</td><td>528 acres</td><td>121</td><td colspan="2" rowspan="2">2.43×10^{9}</td><td colspan="2">2.95×10^{11}</td></tr>
<tr><td>Low Density 0.06/acre</td><td>974 acres</td><td>58</td><td colspan="2">1.41×10^{11}</td></tr>
<tr><td colspan="6" align="right">Total for Ducks in Summer:</td><td colspan="2">4.36×10^{11}</td></tr>
<tr><td rowspan="2">Duck (Winter)</td><td>High Density .366/acre</td><td>528 acres</td><td>193</td><td colspan="2" rowspan="2">2.43×10^{9}</td><td colspan="2">4.69×10^{11}</td></tr>
<tr><td>Low Density 0.078/acre</td><td>974 acres</td><td>76</td><td colspan="2">1.85×10^{11}</td></tr>
<tr><td colspan="6" align="right">Total for Ducks in Winter:</td><td colspan="2">6.54×10^{11}</td></tr>
<tr><td rowspan="2">Goose (Summer)</td><td rowspan="2">2.34/acre</td><td rowspan="2">529 acres</td><td rowspan="2">1238</td><td>Low</td><td>High</td><td>Low</td><td>High</td></tr>
<tr><td>7.99×10^{8}</td><td>4.90×10^{10}</td><td>9.89×10^{11}</td><td>6.07×10^{13}</td></tr>
<tr><td rowspan="2">Goose (Winter)</td><td rowspan="2">2.5/acre</td><td rowspan="2">529 acres</td><td rowspan="2">1323</td><td>Low</td><td>High</td><td>Low</td><td>High</td></tr>
<tr><td>7.99×10^{8}</td><td>4.90×10^{10}</td><td>1.06×10^{12}</td><td>6.48×10^{13}</td></tr>
<tr><td colspan="6" align="right">Total Wildlife (Summer)</td><td>1.76×10^{12}</td><td>6.15×10^{13}</td></tr>
<tr><td colspan="6" align="right">Total Wildlife (Winter)</td><td>2.05×10^{12}</td><td>6.58×10^{13}</td></tr>
</table>

* VADCR, 2003

6. TMDL Development

One of the major obstacles to improving stream water quality is that the potential sources of bacteria are numerous and the dominant sources and/or pathways are generally unknown. This can make it difficult to direct effective cleanup efforts.

Typical pathogen TMDLs are completed by developing watershed-based computer simulations that establish links between sources and in-stream water quality. While effective, the effort required to develop modeled TMDLs can be costly. In an effort to complete pathogen TMDLs in a timely and cost-effective manner, the use of load-duration analyses has been investigated. It has been determined that the load-duration method of calculating a TMDL produces a result only slightly more conservative than if the TMDL had been determined through computer modeling.

The load-duration method essentially uses a record of stream flows over many years to provide insight into the flow conditions under which exceedances of the water quality standard occur. Exceedances that occur under low flow conditions are generally attributed to loads delivered directly to the stream, such as straight pipes or livestock and wildlife directly depositing waste to the stream. Exceedances that occur under high flow conditions are typically attributed to loads that are delivered to the stream in storm water runoff. Exceedances occurring under during normal flows can be attributed to a combination of runoff and direct deposits.

The following sections explain the development of the load-duration TMDL and its associated allocations.

6.1. Load-Duration Curve

Development of a load-duration curve begins with a flow-duration curve. A flow-duration curve is a plot showing the flow magnitude (cfs) along the "y" axis and the frequency of daily average stream flow (%) along the "x" axis. (See Section 6.1.2 for more details). To develop a useful flow-duration curve it is necessary to have several years of flow data for the impaired stream. Where very little flow data exists for the impaired stream, a reference stream must be used, similar to the paired watershed approach used in watershed-based modeling. In the case of Neabsco Creek, there is a record of approximately 1.5 years of measured flow observations. To supplement this flow data, a reference watershed approach was used.

6.1.1. Flow Data

Currently, the USGS does not operate a flow gage on Neabsco Creek. However, the USGS did maintain a gage on Neabsco Creek during the mid 90s (USGS Station 01657850). Station 01657850 was located on the downstream side of the bridge crossing for State Highway 610 at Dale City, approximately 8.6 rivermiles upstream from mouth of the creek. Flow data was collected at this station from 12/22/1994 to 7/9/1996. In order to extend the period of flow record to include the 1998, 2002, 2004, and 2006 assessment periods, a reference stream approach was used. Flows for Neabsco Creek were estimated using Accotink Creek as a reference watershed.

Accotink Creek is located in Fairfax County, Virginia, approximately 13 miles northeast of the Neabsco Creek watershed. Accotink Creek was selected as a reference stream for Neabsco Creek because of its similar land use distribution, location within the same physiographic province, and close proximity to Neabsco Creek. The USGS flow gage for Accotink Creek (01654000) is located just upstream of the Braddock Road (Route 620) bridge crossing. The flow record for this station extends from 10/1/1947 to the present. Figure 9 below shows the Accotink Creek watershed and the location of USGS Station 01654000. Table 16 compares the land use in the Accotink Creek and Neabsco Creek watersheds.

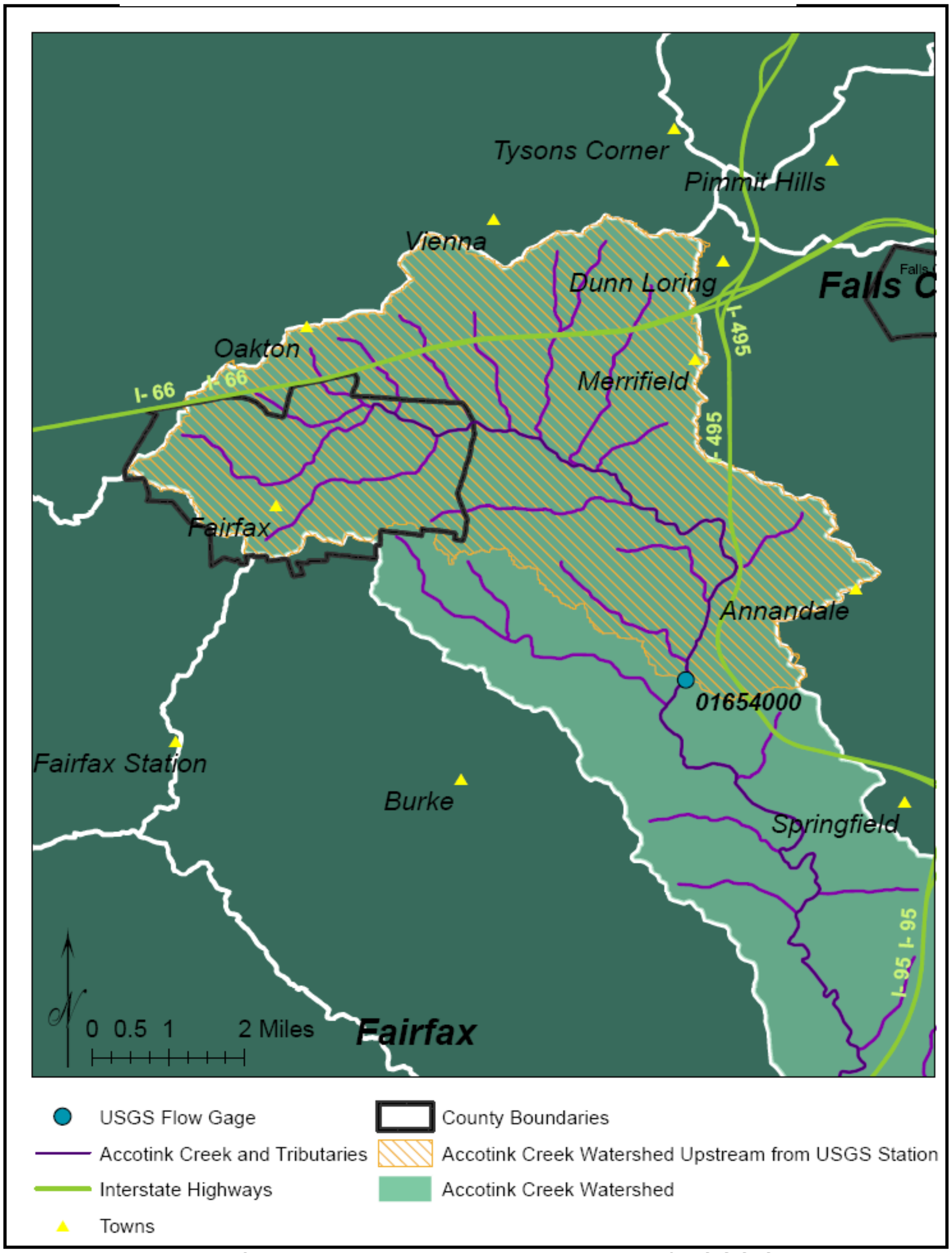

Figure 9. Accotink Creek watershed and the location of USGS Station 01654000.

Table 16. Comparison of the land use in the Accotink Creek watershed and the Neabsco Creek watershed.

	Percent of Total Watershed	
Land Use Type	**Accotink Creek**	**Neabsco Creek**
Developed Lands	62.2	51.2
Wetlands	1.1	0.2
Forested	26.1	33.1
Pasture/Hay/Cropland	10.2	14.9
Open Water	0.0	0.1
Barren land	0.3	0.5
Total:	100.0	100.0

The land use for Accotink Creek and Neabsco Creek are similar in that the watersheds are predominantly urban. Accotink Creek and Neabsco Creek are only thirteen miles apart, so it was assumed that weather events affecting both watersheds were similar. Since precipitation events are assumed to be similar in both watersheds, in can also be assumed that the flows for Neabsco Creek are proportional to the flows in Accotink Creek, dependent on the size of the watershed. Stream flow at the gage station on Accotink Creek is considered to be a function of the watershed area upstream of that point. Because the flows and the area are known for Accotink Creek, that information can be used to determine the flows on Neabsco Creek. See Equation 3 to see an example of how the Neabsco Creek flows were predicted.

$$\frac{Mean\ Daily\ Flow\ of\ \ Ac\cot ink\ Creek}{Acreage\ \ of\ \ Ac\cot ink\ Creek\ Upstream\ \ from\ Flow\ Gage} = \frac{Mean\ Daily\ Flow\ of\ \ Neabsco\ Creek}{Acreage\ \ of\ \ Neabsco\ Creek\ Watershed} \qquad \text{(Equation 3)}$$

$$\frac{11 ft^3 / s}{15{,}377 \text{acres}} = \frac{X}{10{,}009 \text{ acres}}$$

$$X = 7\, ft^3 / s$$

Where: Accotink Creek Mean Daily Flow on 7/30/2005 was 11ft^3/s (*random day was selected for this example)*
Area draining into Accotink Creek above the USGS Station is 15,377 acres
Area draining into Neabsco Creek at the outlet of the impaired watershed is 10,009 acres
X = Estimated Mean Daily Flow on Neabsco Creek at the outlet of the impaired watershed on 7/30/2005.

Using the above method, daily flow values were derived for Neabsco Creek from 1/1/1990 to 9/30/2007. Because there was a period of actual measured flow data for Neabsco Creek (collected from 12/22/1994 to 7/9/1996) a flow analysis was performed to see how well the actual measured flow data matched the estimated flow data that was obtained using the reference watershed. Figure 10 shows a graph of the correlation between actual and predicted flows for Neabsco Creek. This figure reveals a strong correlation between actual and estimated flows (R^2 value of 0.9012).

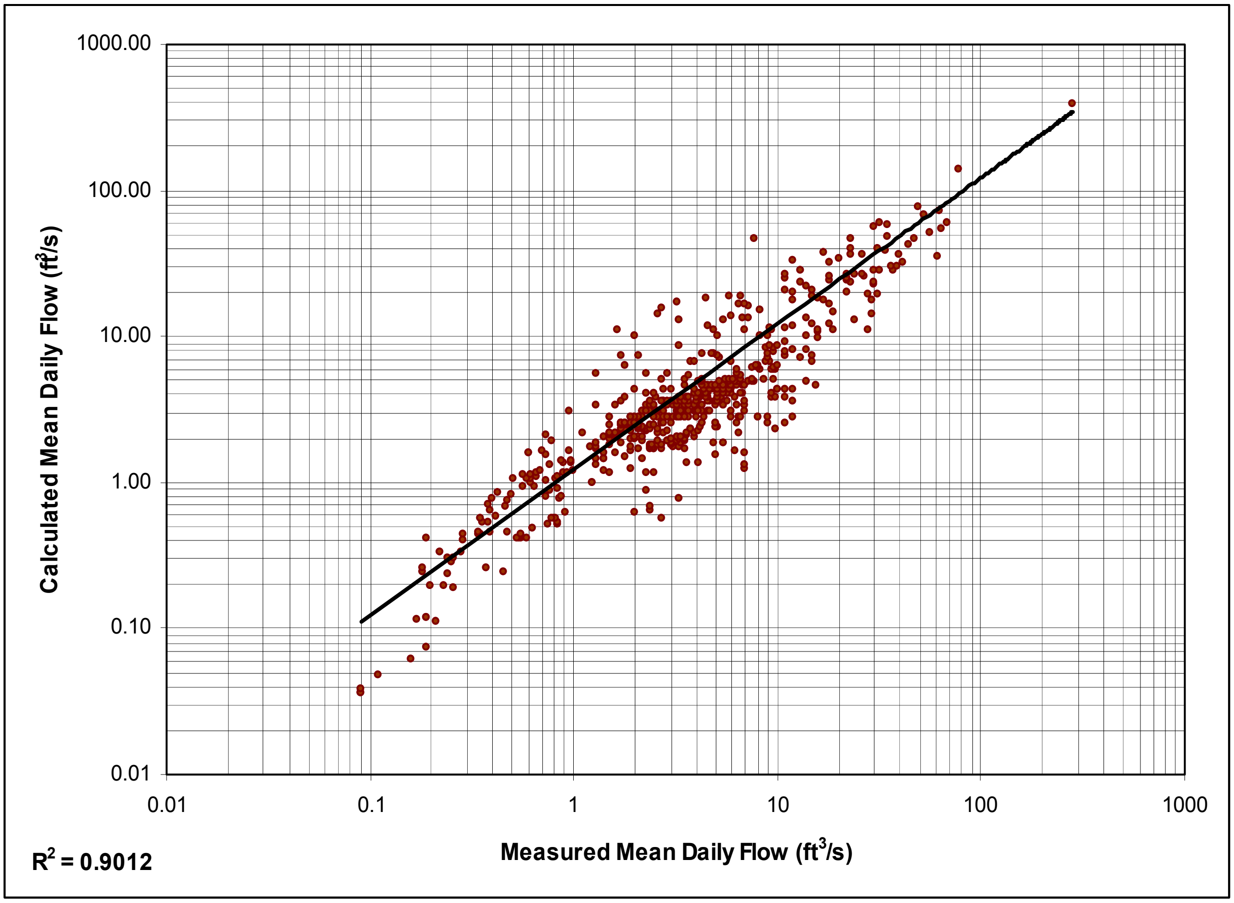

Figure 10. Comparison of actual vs. predicted flows for Neabsco Creek.

6.1.2. Flow-Duration Curves

In order to use the load-duration method to develop a TMDL, a flow-duration curve must be developed for the impaired stream. Daily flows for Neabsco Creek were developed using Accotink Creek as a reference watershed. The drainage area ratio approach (referenced in section 6.1.1) was used to determine what daily flows would be on Neabsco Creek at the outlet point of the impaired watershed (where Neabsco Creek crosses Route 1). A flow-duration curve was developed using estimated flows for Neabsco Creek from 1/1/1990 to 9/30/2007.

A flow-duration curve is a plot showing the flow (measured in ft^3/s) along the "y" axis and the percent of time each daily flow is exceeded along the "x" axis. For example, the flow value corresponding to “1%” is the flow that has been exceeded only 1% of the time for which measurements exist. Likewise, the flow value corresponding to “30%” is the flow that 30% of the historic record exceeds.

The flow-duration curve for Neabsco Creek has been divided into four sections to help illustrate flow conditions. These sections are titled "High Flows", "Transition Flows", "Normal Flows", and "Low Flows". Low flows can be roughly equated to near-drought or drought flows. High flows are near-flood or flood flows. Transition flows are, as implied, neither normal nor high.

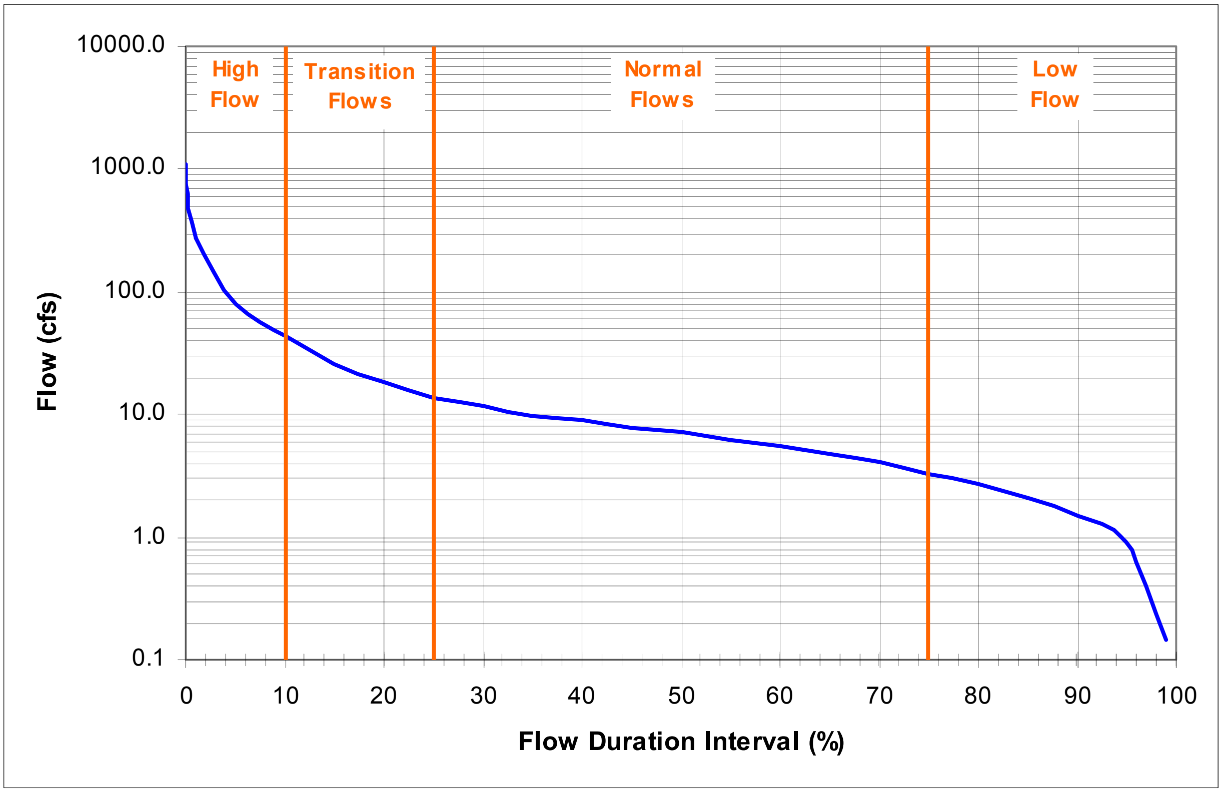

Figure 11. Flow-duration curve for Neabsco Creek.

6.1.3. Load-Duration Curve

As noted in Section 3, the majority of recent in-stream water quality observations on Neabsco Creek were collected at Station 1ANEA002.89. Therefore, this station is the focus of the load-duration analysis on Neabsco Creek. The station is also located at the furthermost downstream point of the impaired watershed, and thus captures everything upstream.

A load-duration curve is developed by multiplying each flow level along the flow-duration curve by the applicable water quality criterion (instantaneous criterion of 235 cfu/100mL) and required unit conversions. The resulting curve represents the loading capacity of the stream at the water quality criterion for each flow interval, in other words, the Total Maximum Daily Load (TMDL) for the stream. Figure 12 shows the load-duration curve for Neabsco Creek.

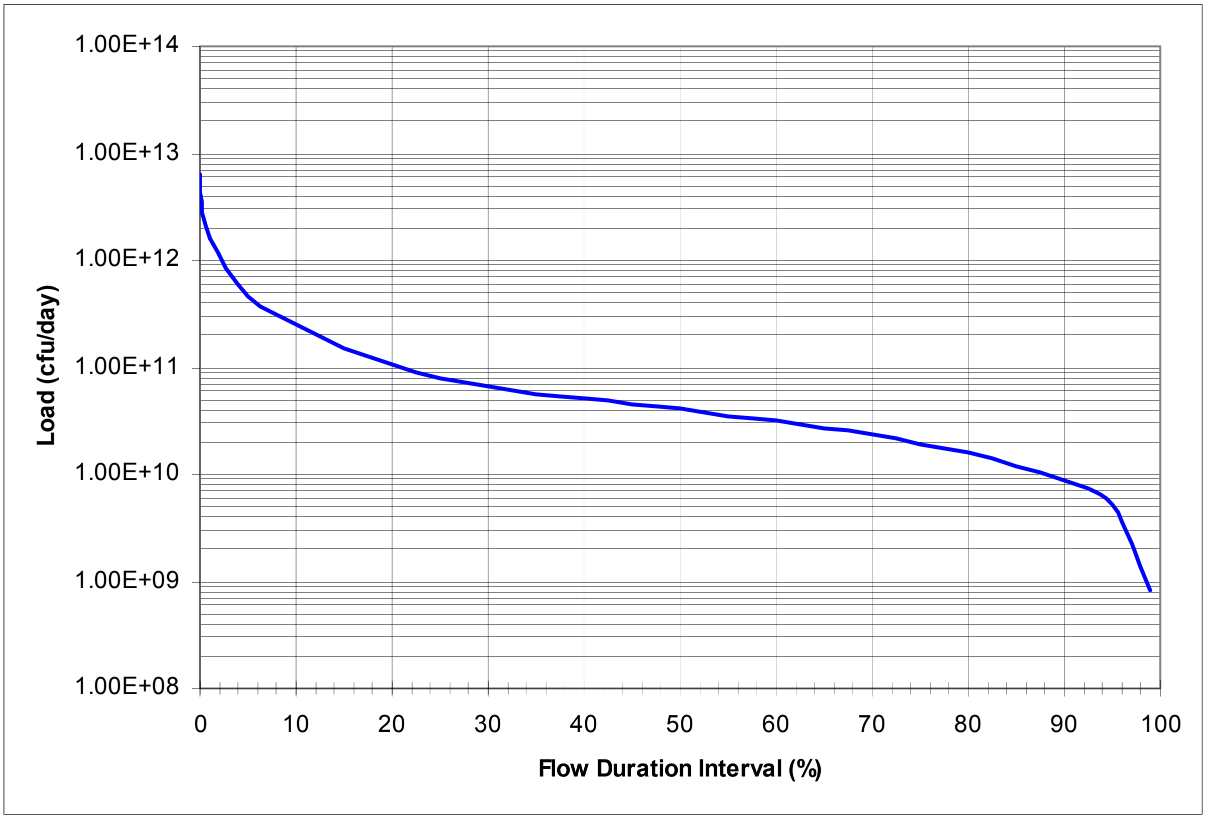

Figure 12. Load-duration curve for Neabsco Creek.

The next step in the process is to plot the water quality bacteria samples along the load-duration curve to see where exceedances of the criterion exist. In order to plot existing fecal coliform (FC) data against the *E. coli* (EC) criterion/TMDL line, it was necessary to translate the FC data to EC data. Translation of FC data to EC data was achieved by using a translator equation that was developed from a regression analysis of 493 paired FC/EC data sets from the DEQ's statewide monitoring network (VA DEQ Guidance Memo No. 03-2012, 2003). Equation 4 below shows the resulting translation from the regression analysis:

$$EC \log_2 = -0.0172 + 0.91905 * FC \log_2 \qquad \text{(Equation 4)}$$

This translator equation may cause a slightly different number of water quality standard exceedances when looking at non-translated versus translated data. This is because of the variance of the translator equation related to specific fecal coliform results near the water quality standard.

By plotting these observed loads on the load-duration curve, the number and pattern of exceedances of the water quality criterion (TMDL) can be analyzed. The load-duration curve and observed bacteria data from 11/28/2000 to 8/28/2007 for Neabsco Creek at Station 1ANEA002.89 are shown in Figure 12. The TMDL line has been plotted for the instantaneous *E. coli* standard of 235 cfu/100mL.

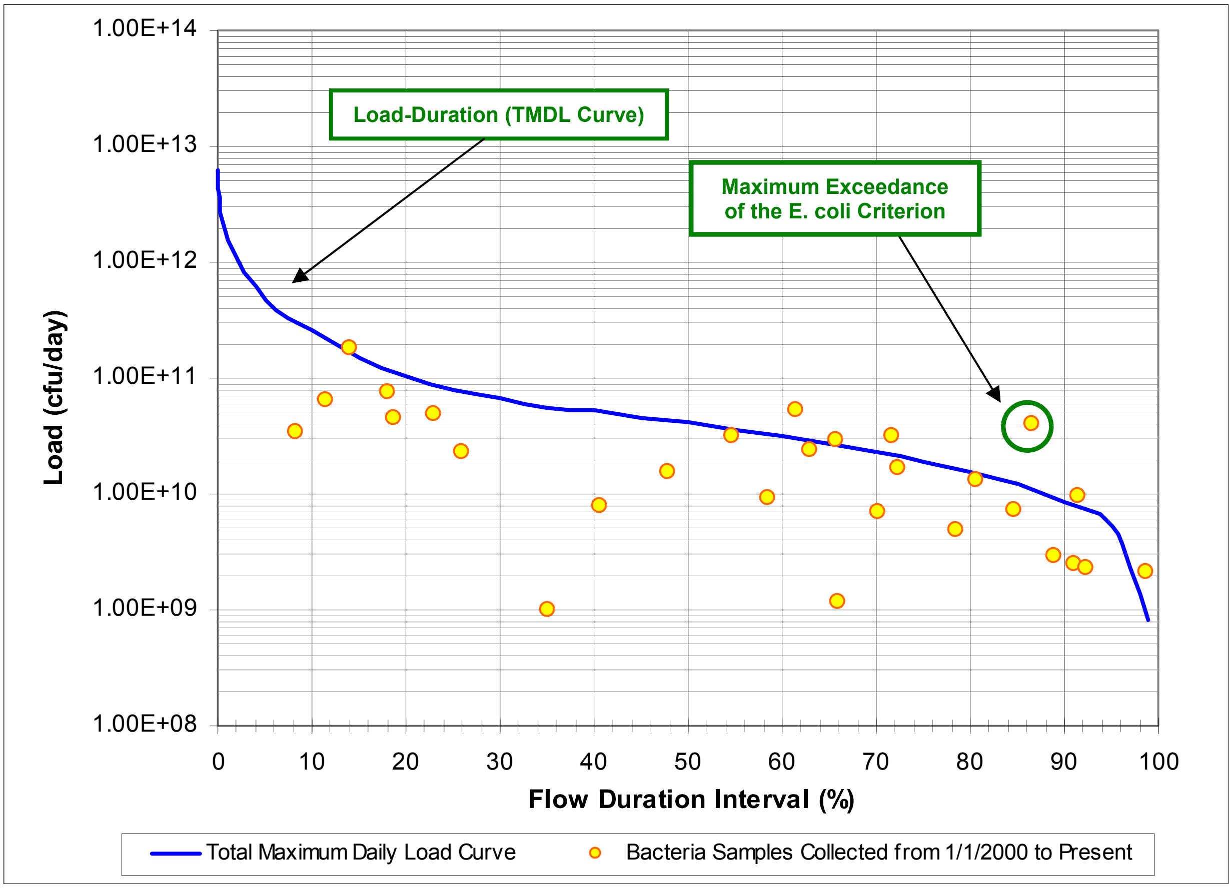

Figure 13. Load-duration curve and observed bacteria data for Neabsco Creek at Station 1ANEA002.89 from 11/28/2000 to 8/28/2007.

Figure 13 suggests that exceedances of the water quality standard generally occur under normal and low flow conditions. The highest exceedance of the water quality standard occurred during low flow (87% flow interval, 2 ft^3/s, circled in green). This represents the flow condition under which the largest bacteria reduction is required in order to meet water quality standards. The translated load at that point is 4.05×10^{10} cfu/day. Under the instantaneous *E. coli* criterion of 235 cfu/100mL, this load would have to be reduced by 71% to an allowable load of 1.16×10^{10} cfu/day in order to meet water quality standards.

As can be seen on Figure 13, the allowable daily load is variable with flow along the curve and represents simply the *E. coli* criterion multiplied by the applicable flow condition and the proper unit conversions. The full calculation with unit conversions is presented in Appendix C. Because the allowable load is variable with flow and represents simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions, the TMDL condition will be selected to reflect the flow-varying nature of bacteria impairments.

In order to capture all flow conditions, the TMDL will be selected using the 99th load percentile, i.e. for the 1% flow-duration interval. This represents the maximum flow conditions determined for Neabsco Creek (only 1% of the flows exceed this value). To determine the necessary load reductions at this maximum flow condition, a second curve must be drawn through the highest exceedance described above. The second curve represents the magnitude of the highest observed exceedance if it were to occur over any flow condition. The graph of the load-duration curve with the maximum exceedance curve is presented in Figure 14.

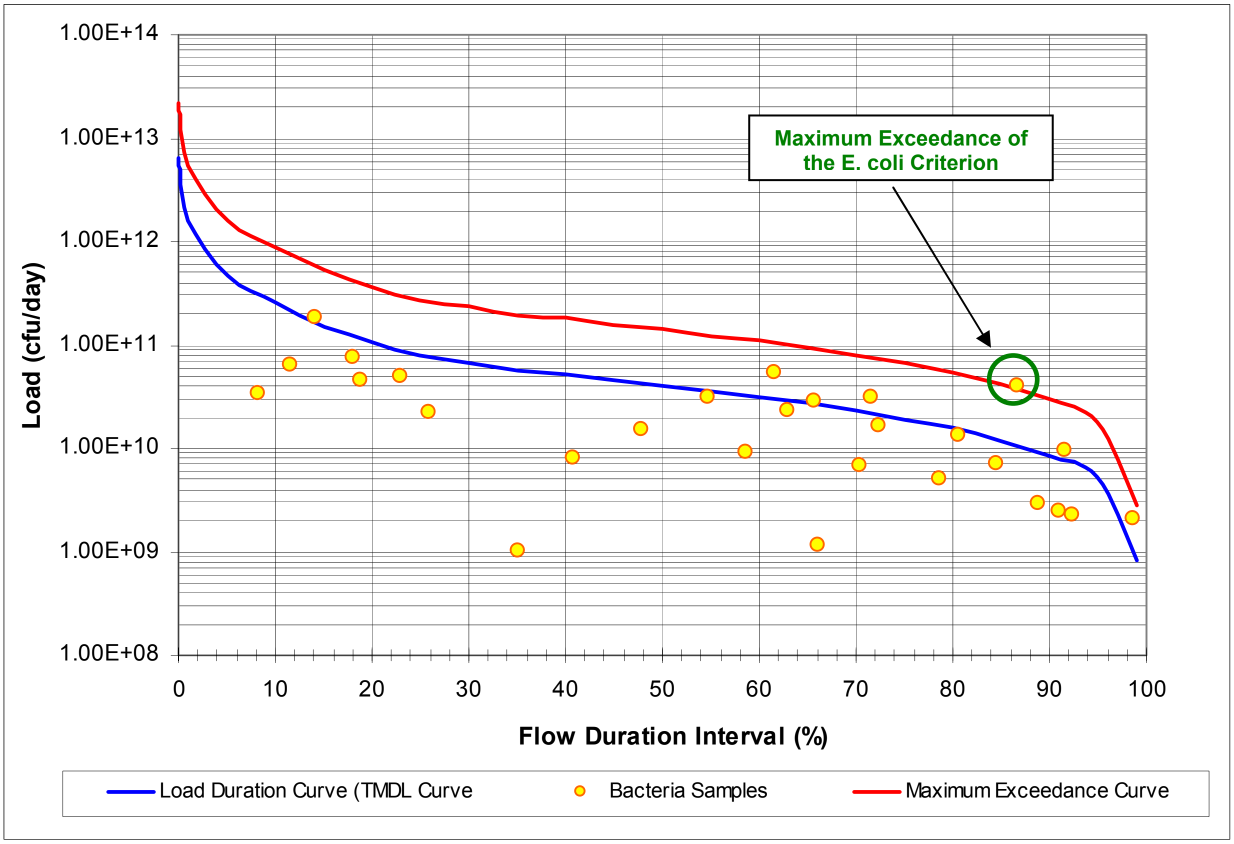

Figure 14. Load-duration curve with maximum exceedance curve for Neabsco Creek at Station 1ANEA002.89.

6.2. TMDL

A Total Maximum Daily Load (TMDL) consists of point sources (WLAs); non-point sources (LAs), where the non-point sources include natural/background levels); and a margin of safety (MOS), where the MOS may be implicitly or explicitly defined. TMDLs also contain an expansion factor for growth of existing or new point source WLAs. This TMDL definition is typically illustrated by the following equation:

TMDL = WLAs (Including Future Growth Factor) + LAs + MOS (Equation 5)

Simply put, a TMDL is the amount of a pollutant that a water body can receive and still meet water quality standards for that pollutant. In the case of load-duration bacteria TMDLs, the TMDL is expressed as the total number of colony forming units (cfu) per day for the 99th percentile load. The estimated 99th percentile flow for Neabsco Creek is 273 ft^3/s. From this information an average daily *E. coli* load and TMDL can be calculated from the maximum exceedance and TMDL curves. This is represented graphically in Figure 15.

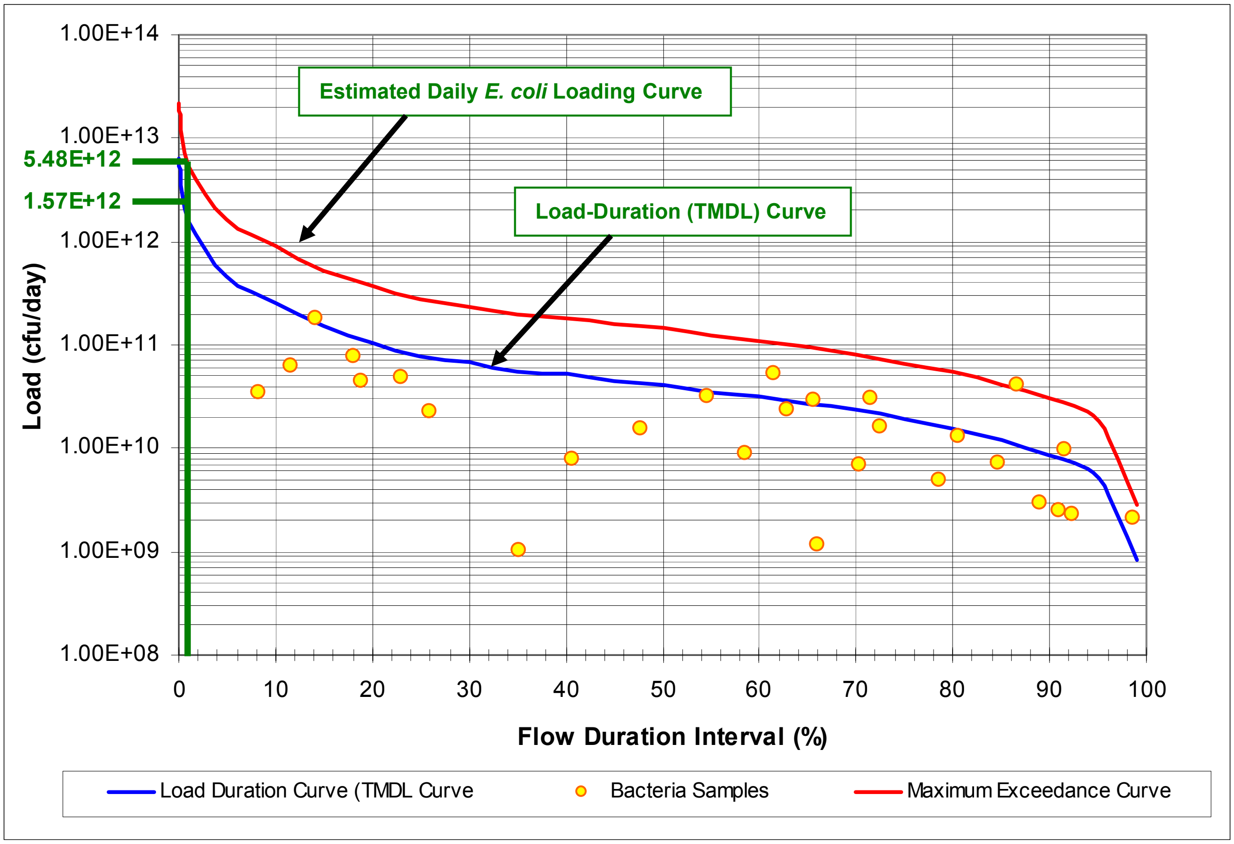

Figure 15. Load-duration curve illustrating the TMDL and estimated daily *E. coli* load for Neabsco Creek at Station 1ANEA002.89.

For Neabsco Creek the one percent flow-duration interval existing daily *E. coli* load is 5.48 x 10^{12} cfu/day. This number represents the existing *E. coli* load in the watershed. The daily TMDL load under one percent flow-duration is 1.57 x 10^{12} cfu/day. The represents the *E. coli* loading that could be present in the watershed and Neabsco Creek would still meet the water quality standards for the recreational use. These two values are used to calculate required reductions. A 71% reduction in the existing bacteria load is required for Neabsco Creek to reach its TMDL goal.

As mentioned in Equation 5, a TMDL is made up of a WLA, LA and MOS. The waste load allocation is the load allocated to permitted point sources in the watershed (See section 5.2). By subtracting the load for VPDES point sources from the TMDL load, the load allocations for land based loads (MS4 storm water permits, and non-point source loads) can be determined. Loads from urbanized and developed lands within the watershed were classified as MS4 loads and included in the WLA (See Section 5.2.2). The load from the remaining forested lands were categorized as the contribution from non-point sources and listed under the LA. The LA takes into account the natural/background levels of bacteria present in the forested stream corridors along Neabsco Creek and its tributaries. Seventy-eight percent of the land based loads were attributed to MS4 entities within the watershed, and the remaining 22% of the loads were counted under the non-point source load allocation. The TMDL, WLA and LA are presented as daily loads in Table 17 for Neabsco Creek. Tables 18 and 19 show the WLA for VPDES and MS4 point sources, respectively.

Table 17. TMDL for *E. coli* in the Neabsco Creek watershed (cfu/day).

WLA[2]	LA[3]	MOS	TMDL[1]
1.27×10^{12}	2.97×10^{11}	Implicit	1.57×10^{12}

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – WLA includes an allocation for individual VPDES permits and MS4 permits. The point sources permitted to discharge in the Neabsco Creek watershed are presented in section 5.2. The WLA reflects an allocation for growth in the watershed. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as determined by the VADEQ Virginia Pollutant Discharge Elimination System program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.
3 – MS4 permits in the Neabsco Creek watershed are listed in section 5.2.2. MS4 areas account for approximately 78% of the Neabsco Creek watershed. Thus, 78% of the land-based loads are attributed to the MS4 entities, and will be included along with the other VPDES point sources in the WLA. The remaining 22% of the land-based, non-point source loads will be listed under the load allocation, and account for the natural/background levels of bacteria that are present in the forested corridors along Neabsco Creek and its tributaries.

Table 18. WLA for VPDES Permits.

VPDES Permit Number	Facility Name	Receiving Stream	Design Flow (MGD)[1]	Effluent Limit (cfu/100mL)	Waste Load Allocation (cfu/year)	Waste Load Allocation (cfu/day)
VA0024724	Dale Service Corporation Section 1	Unnamed Tributary to Neabsco Creek	4.6	126	8.01×10^{12}	2.19×10^{10}
VA0024678	Dale Service Corporation Section 8	Neabsco Creek	4.6	126	8.01×10^{12}	2.19×10^{10}
				Existing WLA	1.60×10^{13}	4.39×10^{10}
Expansion Matrix[2]						
					Total x 2	8.78×10^{10}
					Total x 5	2.20×10^{11}

[1]This is the maximum permitted design flow for the facility.
[2]The five-times load (2.20×10^{11}cfu/day) will be the VPDES permit portion of the WLA. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but the growth-expanded allocation will be allocated to both new and existing permits as determined by the VADEQ VPDES program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.

Table 19 – WLA for MS4 Permits.

Permit Number	MS4 Permit Holder	WLA (cfu/day)[1]
VA0088595	Prince William County	1.05×10^{12}
VAR040100	Prince William County Public Schools	
VAR040062	VDOT – Northern Urban Area	
VAR040095	Northern Virginia Community College	

[1]See Section 6.2 for further explanation of how the WLA for MS4 areas was determined.

7. Allocations

7.1 Reductions

The existing *E. coli* load and the allowable (TMDL) load from section 6.2, together with the WLA from the permitted bacteria sources in section 5.2, were inserted into Tables 20 and 21 below to determine the required reductions (The full calculations are presented in Appendix C). Reductions will not apply to the VPDES permitted point sources, but rather, to the MS4 permit holders and the non-point sources of pollution. Reductions are not required for the VPDES permits because they have already been mandated to discharge at or below the water quality criterion for *E. coli*.

Table 20. Required reductions for the Neabsco Creek watershed.

Load Category		Existing Daily EC Load (cfu/day)	Allowable EC Loads (cfu/day)	Required Reduction
Waste Load Allocation (WLA)	VPDES Permitted Point Sources[1]	4.39×10^{10}	2.20×10^{11}	N/A
	MS4 Permits	4.24×10^{12}	1.05×10^{12}	75%
Load Allocation (LA)		1.20×10^{12}	2.97×10^{11}	75%
Margin of Safety		Implicit		
Total		5.48×10^{12}	1.57×10^{12}	71%

[1]*The existing load for VPDES point sources (4.39 x 10^{10} cfu/day) was increased by a five-times factor in order to account for future growth of point sources in the watershed, making the allowable load for VPDES point sources 2.20 x 10^{11} cfu/day. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but the growth-expanded allocation will be allocated to both new and existing permits as determined by the VADEQ VPDES program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. Because the VPDES point sources are already required to discharge at water quality standards, no reductions are required from VPDES point sources.*

7.2. Margin of Safety

Each TMDL requires a margin of safety. The MOS is intended to add a level of safety to account for any inherent uncertainty in the TMDL development process and the data used in the development. The MOS may be either implicit or explicit. An implicit margin of safety relies on the conservative nature of the assumptions, values, and methods used to calculate a TMDL whereas an explicit margin of safety is a value (typically a percentage) applied at some point during the TMDL calculation.

In the Neabsco Creek TMDL, an implicit MOS was incorporated through the use of conservative analytical assumptions. The key conservative assumption is the use of the single-most extreme water quality exceedance event to develop a maximum exceedance curve over the entire range of flow conditions. Additionally, the load-duration method of TMDL development has been evaluated against TMDLs that were developed using computer modeling. The results showed the load-duration method to be slightly more conservative.

7.3. Allocations

In order to apply the reduction calculated above, the daily *E. coli* loads had to be allocated to each of the four source categories identified in the BST analysis. Table 21 shows the distribution of the daily *E. coli* load among sources (derived by multiplying the daily load by the weighted BST source percent for each of the four source groups), the reduction applied to each source, and the allowable loading for each source, for Neabsco Creek. Reductions are only applied to the MS4 and non-point sources. Theoretically these reductions would reduce the *E. coli* load to the water quality criterion, resulting in zero exceedances.

Table 21. Daily load distribution, reduction, and allowable load by source category for Neabsco Creek.

	WLA (excluding MS4) (cfu/day)	MS4 and LA (cfu/day)				Totals (cfu/day)
	VPDES Point Sources	Humans 0%	Pets 20%	Livestock 1%	Wildlife 79%	
Existing Daily Load	4.39×10^{10}	0	1.09×10^{12}	5.44×10^{10}	4.29×10^{12}	5.48×10^{12}
Required Reductions	N/A	N/A	75%	75%	75%	71%
Allowable Loads /TMDL Load	*2.20×10^{11}	0	2.70×10^{11}	1.35×10^{10}	1.07×10^{12}	1.57×10^{12}

** Includes an allocation for the future growth of point sources in the watershed.*

7.4. Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Neabsco Creek is protected during times when conditions are most conducive for water quality criteria exceedances.

Critical conditions are important because they describe the factors that combine to cause exceedances of the water quality standards, and will help in identifying actions that will assist in meeting water quality standards. The sources of bacteria for Neabsco Creek are a mixture of low and normal flow-driven sources. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore, the critical conditions for Neabsco Creek were addressed during TMDL development.

7.5. Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatological patterns. The load-duration approach allows the pattern of water quality exceedances to be examined for seasonal variations. The load-duration method used to develop this TMDL implicitly incorporates the seasonal variations of precipitation and runoff by looking at the highest water quality exceedance and applying it to the entire stream flow record when calculating the TMDL.

8. Implementation and Reasonable Assurance

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

8.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

8.2 Staged Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairment on Neabsco Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent “TMDL Implementation Plan Guidance Manual”, published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

In general, Virginia intends for the required reductions of bacteria for Neabsco Creek to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in an agricultural watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, BMPs aimed at controlling urban wash-off from parking lots and roads, as well as more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning could be implemented to help reduce overall bacteria loads to a stream.

The iterative implementation of BMPs in the watershed has several benefits:

1. Enables tracking of water quality improvements following BMP implementation through follow up stream monitoring.
2. Provides a measure of quality control, given the uncertainties inherent in computer simulation modeling.
3. Provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements.
4. Ensures that the most cost effective practices are implemented first.
5. Allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

8.3 Implementation of Wasteload Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

8.3.1 Treatment Plants

This TMDL does not require reductions from municipal or industrial treatment plants.

8.3.2 Stormwater

VADEQ and DCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while DCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

Municipal Separate Storm Sewer Systems – MS4s

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the iterative implementation of programmatic BMPs. BMP effectiveness would be determined through permittee implementation of an individual control strategy that includes a monitoring program that is sufficient to determine its BMP effectiveness. As stated in EPA's Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002, "The NPDES permits must require the monitoring necessary to assure compliance under the permit limits." Ambient instream monitoring would not be an appropriate means of determining permit compliance. Ambient monitoring would be appropriate to determine if the entire TMDL is being met by all attributed sources.

This is in accordance with recent EPA guidance. If future monitoring indicates no improvement in the quality of the regulated discharge, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a permit compliance issue. Any changes to the TMDL resulting from water quality standards changes on Accotink Creek would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed as a condition of the MS4 permit. An implementation plan will identify types of corrective actions and strategies to obtain the load allocation for the pollutant causing the water quality impairment. Permittees will be required to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL. For example, MS4 permittees regulate erosion and sediment control programs that affect discharges that are not regulated by the MS4 permit. The implementation of the WLAs for MS4 permits will focus on achieving the percent reductions required by the TMDL, rather than the individual numeric WLAs.

Additional information on Virginia's Stormwater Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm

8.3.3 TMDL Modifications for New or Expanding Dischargers

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/waterguidance/

8.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

8.5 Stage I Implementation Goal

As stated in Section 7.0 the TMDL for Neabsco Creek requires a 71% reduction in MS4 and non-point source loadings in order to attain a 0% exceedance of water quality standards. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels and their associated exceedance rates were assessed. Reduction curves similar to the max exceedance/reduction curve of Figure 14 were plotted on the Neabsco Creek load-duration curve. These reduction curves are presented in Figure 16.

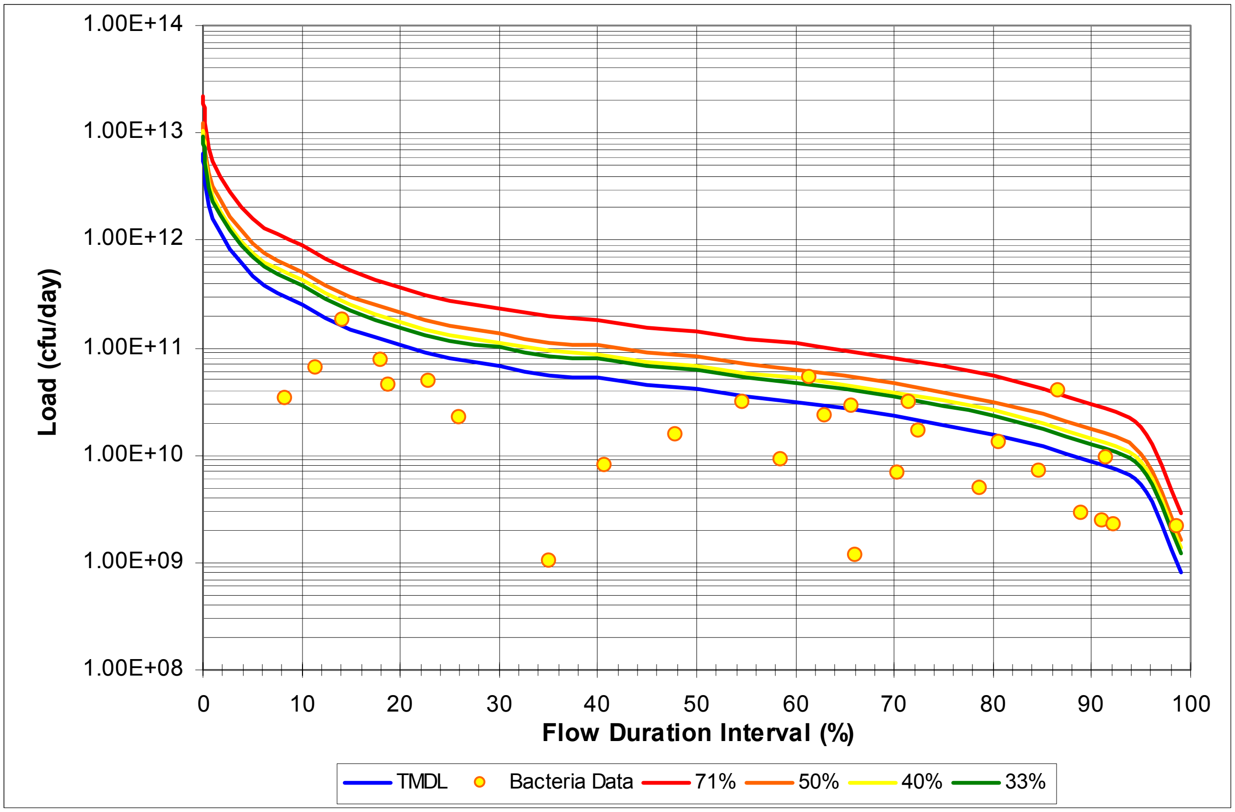

Figure 16. Load-duration curve illustrating the TMDL and reduction curves for Neabsco Creek at Station 1ANEA002.89.

For Neabsco Creek, the theoretical exceedance rates for the various load reductions are shown below in Table 22. These were calculated by dividing the number of *E. coli* load data points above each respective percent reduction curve by the total number of *E. coli* load data points (28).

Table 22. Load reductions and water quality standard exceedance rates.

Load Reduction	71%	50%	40%	33%	0% (Current Load)
Exceedance Rate	0%	4%	7%	10.7%	25%

Based on the reduction analysis presented above and a goal of measurable water quality improvement, a suitable Stage I reduction level would be 33%. An approximate 33% reduction in bacteria would theoretically allow for a less than 10.5% exceedance rate, which means that the stream could be taken off of the impaired waters list. Table 23 presents the Stage I load allocations based on a 33% reduction of in-stream loads. Table 24 presents the overall reduction attained by eliminating anthropogenic contributions and making no reductions to wildlife contributions. It should be noted in Table 24 that even after reducing all anthropogenic loads by 100%, neither the TMDL goal nor the Stage I Implementation Goal would be met due to the wildlife load alone. Calculations for Tables 23 and 24 are found in Appendix C.

Table 23. Stage I reduction goals.

	WLA (excluding MS4) (cfu/day)	MS4 and LA (cfu/day)				Totals (cfu/day)
	Permitted Point Sources	Humans 0%	Pets 20%	Livestock 1%	Wildlife 79%	
Daily Load	4.39 x 10^{10}	0	1.09 x 10^{12}	5.44 x 10^{10}	4.29 x 10^{12}	5.48 x 10^{12}
Reduction	N/A	N/A	37%	37%	37%	33%
Target Stage I Daily Load	*2.20 x 10^{11}	0	6.90E+11	3.45E+10	2.73E+12	3.67 x 10^{12}

** Includes an allocation for the future growth of point sources in the watershed.*

Table 24 – Reductions from anthropogenic sources.

	WLA (non-MS4) (cfu/day)	MS4 and LA (cfu/day)				Totals (cfu/day)
	Permitted Point Sources	Humans 0%	Pets 20%	Livestock 1%	Wildlife 79%	
Daily Load	4.39 x 10^{10}	0	1.09 x 10^{12}	5.44 x 10^{10}	4.29 x 10^{12}	5.48 x 10^{12}
Reduction	N/A	N/A	100%	100%	0%	20%
Target Daily Source Load	**2.20 x 10^{11}	0	0	0	4.29 x 10^{12}	*4.51 x 10^{12}

** Even after reducing all anthropogenic loads by 100%, either the TMDL goal (1.57 x 10^{12}) or the Stage 1 goal (3.67 x 10^{12}) are met due to the contribution of wildlife alone.*

** *Includes an allocation for the future growth of point sources in the watershed.*

8.6 Reasonable Assurance for Implementation

8.6.1. Follow-Up Monitoring

VADEQ will continue to monitor Neabsco Creek in accordance with its ambient monitoring program. Watershed stations will continue to be monitored bi-monthly on a 6 year rotational schedule in the future. VADEQ and VADCR will continue to use data from the monitoring station on Neabsco Creek to evaluate reductions in bacteria counts and the effectiveness of the TMDL in attainment of water quality standards. Watershed sampling includes field parameters (temperature, pH, dissolved oxygen, conductivity), bacteria, nutrients and solids. Future bacteria sampling will consist of *E. coli* sampling only, since the interim fecal coliform bacteria has been phased out at Station 1ANEA002.89 because twelve *E. coli* samples have been collected.

8.6.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and waste load allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

8.6.3. Implementation Funding Sources

The implementation on pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at http://www.dcr.virginia.gov/sw/wqia.htm

8.6.4. Wildlife Contributions and Water Quality Standards

Addressing Wildlife Contributions

In some streams for which TMDLs have been developed water quality modeling and analysis indicate that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. Virginia and EPA are not proposing the elimination of natural wildlife to allow for the attainment of water quality standards. However, managing overpopulations of wildlife remains an option available to local stakeholders. During the implementation plan development phase of a TMDL process, if the Department of Game and Inland Fisheries (DGIF), in consultation with local government and land owners, determine that a population of resident geese, deer or other wildlife is a at “nuisance” levels, measures to reduce such populations may be deemed acceptable if undertaken under the supervision, or issued permit, of DGIF or the U.S. Fish and Wildlife Service as appropriate. Additional information on DGIF’s wildlife programs can be found by accessing their website at the following address: http://www.dgif.virginia.gov/hunting/va_game_wildlife/.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a Stage I scenario such as those presented previously in this chapter. The pollutant reductions in the Stage I scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the Stage I scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained.

If water quality standards are not being met, a use attainability analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the TMDL may have been very small and infrequent and within the margin of error.

Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because of one or more of the following conditions:

1. Naturally occurring pollutant concentration prevents the attainment of the use.
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation.
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate the modification in such a way that would result in the attainment of the use.

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection.
6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the State Water Control Board (SWCB) as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment during this process.

For bacteria, Virginia has adopted a new "secondary contact" category for protecting the recreational use in state waters. "Secondary contact recreation" means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". In order to re-designate a state water from primary to secondary contact recreation use, a UAA as described above is necessary. The secondary contact recreation criteria can be found at http://www.deq.state.va.us/wqs/documents/WQS06_EDIT_001.pdf.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed."

Use Attainability Analysis for Neabsco Creek

In the case of Neabsco Creek, the possibility of doing a use attainability analysis is somewhat questionable, due to a bacteria impairment that exists downstream. Neabsco Creek flows into Neabsco Bay, which is an embayment of the Potomac River. In the 2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report, and the 2006 305(b)/303(d) Water Quality Assessment Integrated Report (VADEQ, 2004, and 2006) Neabsco Bay was found to be not supporting for the recreational designated use due to exceedances of the water quality criterion for bacteria. In the 2004 assessment, eight of 38 samples (21.1%) exceeded the instantaneous fecal coliform criteria. In the 2006 assessment, seven of 26 samples (26.9%) exceeding the instantaneous fecal coliform bacteria criteria. Sampling for both assessment periods were performed at Station 1ANEA000.57.

Because the Potomac River and its embayments are often used for recreational purposes such as boating, fishing, swimming, and water sports, it is questionable as to whether a use attainability analysis for the upstream Neabsco Creek bacteria impairment would be appropriate, since Neabsco Creek is a direct tributary to Neabsco Bay. This and other issues would be explored if a use attainability analysis study is deemed to be necessary.

9. Public Participation

Public participation in the TMDL process plays a vital role in developing a TMDL that is accurate, reflecting actual conditions in the watershed, and can be supported by local stakeholders through implementation measures to achieve improvements in water quality. Two Technical Advisory Committee (TAC) Meetings were held for this project, both at the Northern Regional Office of DEQ in Woodbridge, Virginia. The TAC included representatives from the Prince William County Government, the Prince William County Soil and Water Conservation District, the Virginia Department of Conservation and Recreation, the Prince William County Health Department, the Dale Service Corporation, and a local adopt-a-stream program.

The first TAC Meeting was held on June 19, 2007. The purpose of this first TAC meeting was to discuss the process for TMDL development, review the draft source assessment input, and present the draft load-duration curve for the impaired water body. Thirteen people attended. Copies of the presentation materials were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register on June 11, 2007. There was a 30 day-public comment period following the first TAC meeting, however, no written comments were received.

The second TAC Meeting was held on July 18, 2007. The purpose of this second TAC meeting was to review the TMDL process and follow-up on comments received during the first TAC Meeting. Eleven people attended. Copies of the presentation materials were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register on July 9, 2007. There was a 30 day-public comment period following the first TAC meeting, however, no written comments were received.

A public meeting was held in Woodbridge, Virginia on December 13, 2007, to present the draft TMDL report. Five people attended. Copies of the presentation materials and draft report were available at the meeting and on the DEQ website. The meeting was public noticed in the Virginia Register and a meeting announcement was sent to several local newspapers. Flyers announcing the meeting were sent to all members of the TAC for distribution. There was a 30 day-public comment period following the public meeting, during which one set of comments were received.

10. References

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Appendix A

Glossary

Note: All entries in italics are taken from USEPA (1998). All non-italicized entries are taken from MapTech (2002).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (non-point or point) or to natural background sources. (A waste load allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future non-point source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or non-point source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of water bodies.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally non-point source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal*

Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the water body in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Designated uses. *Those uses specified in water quality standards for each water body or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the*

Federal Clean Water Act.

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Existing use. *Use actually attained in the water body on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural* *or industrial pollutants and leaking underground storage tanks.*

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future non-point sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and non-point source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the* *calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.
MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Non-point source. *Pollution that originates from multiple sources over a relatively large area. Non-point sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed water body.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

Permit. *An authorization, license, or equivalent control document issued by EPA or an* *approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Phased approach. *Under the phased approach to TMDL development, load allocations and waste load allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when non-point sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 ml geometric mean limit).

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into water bodies or is routed into a drain or sewer system.*

Stream flow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "stream flow" uniquely describes the discharge in a surface stream course. The term "stream flow" is more general than "runoff" since stream flow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological,* *morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a water body; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of non-point source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for non-point sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving water body. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

DACS. Department of Agriculture and Consumer Services.

DCR. Department of Conservation and Recreation.

DEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Waste load allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a water body. It is a measure of a water body's ability to support beneficial uses.*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

Appendix B

Antibiotic Resistance Analysis (MapTech)

When performing ARA, isolates (colonies picked from membrane filtration plates) of *E. coli* or *Enterococcus* are transferred to a 96-well tissue culture plate (one isolate per well) containing a selective liquid medium. The 96-well plates are incubated and confirmed as *E. coli* or *Enterococcus* by color changes in the liquid after incubation (Figure 1). Antibiotic stock solutions are prepared and each of twenty-eight or more antibiotic/concentrations is added separately to flasks of autoclaved and cooled Trypticase Soy Agar (TSA) from the stock solutions to achieve the desired concentration, and then poured into sterile 15x100mm petri dishes.

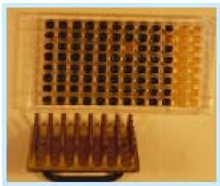


Figure 1. 96-well plate after incubation.

Control plates (no antibiotics) are included with each set. Isolates are transferred from the 96-well plate using a stainless steel 48-prong replica plater (Sigma). The replicator is flame-sterilized (95% ethanol) after inoculation of each TSA plate. Resistance to an antibiotic is determined by comparing each isolate to the growth of that isolate on the control plate. A one (1) is recorded for growth and a zero (0) is recorded for no growth (Figure 2). This is repeated for each isolate on each of the 30 antibiotic plates to develop a profile.

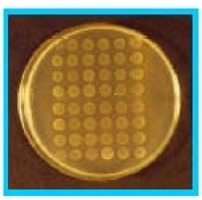


Figure 2. TSA control plate (with no antibiotics) showing growth of all 48 isolates.

The profile is then compared against the known source library to determine the source of the isolate (see data analysis section). The basic process is the same for all approaches, that is, a data base of known sources analyzed using the BST method of choice must be developed and samples of unknown bacterial origin are collected, analyzed and compared to the known source database. For studies, such as Total Maximum Daily Loads (TMDL), we recommend the ARA procedure due to typical cost constraints. Typically we analyze 24 isolates per unknown source (e.g. stream or well water) sample. This provides measurements of the proportion of a given source that are in increments of approximately 4%. If more precision is required, 48 isolates can be analyzed, resulting in resolution of approximately 2%. If the sampling is to be done in a geographical area where a database of known sources has not been developed, we will need to collect samples from known sources (i.e. human, livestock, wildlife) and compare them to our existing databases to determine if one of our existing databases is compatible with the study area. Twenty-four isolates from each of these samples will be analyzed. If no existing database is compatible, we will need to develop a database for the study area. The number of samples needed depend on variability of source samples. We have had a good deal of success in the past by using existing databases through obtaining known source samples from each group (i.e. human, livestock, wildlife) in the study area and comparing them to existing databases.

Appendix C

Calculations

Calculations

Allowable Daily Load Calculation from Section 6.1.3

$$TMDL\ cfu/day = Q\frac{ft^3}{s}x\frac{7.48\ gal}{ft^3}x\frac{3.7854L}{gal}x\frac{1000mL}{L}x\frac{235cfu}{100mL}x\frac{60s}{\min}x\frac{60\min}{hour}x\frac{24hours}{day}$$

Where:

TMDL cfu/yr	=	Allowable load in cfu/yr
235 cfu/100 ml	=	Instantaneous *E. coli* standard
Q ft^3/s	=	Flow in cubic feet per second
cfu	=	*E. coli* colony forming units.
l	=	liters
ml	=	milliliters
s	=	seconds
min	=	minutes
gal	=	gallons

Calculations for Table 20:

Known Values:

Existing Daily Load (All Sources)	=	5.48×10^{12} (cfu/day)
Total Maximum Daily Load	=	1.57×10^{12} (cfu/day)
Existing VPDES Point Source Load	=	4.39×10^{10} (cfu/day)

Calculation for Existing Load from Land Based Sources (MS4 and Non-Point Sources):
= Total Existing Load – VPDES Point Source Load
= $5.48 \times 10^{12} – 4.39 \times 10^{10}$
= 5.44×10^{12} (cfu/day)

Calculation for Existing MS4 Load:
= 78% of the Existing Load from Land Based Sources (See Section 5.2.2)
= $.78 \times 5.44 \times 10^{12}$
= 4.24×10^{12} (cfu/day)

Calculation for Existing LA Load:
= 22% of the Existing Load from Land Based Sources (See Section 5.5.5)
= $.22 \times 5.44 \times 10^{12}$
= 1.20×10^{12} (cfu/day)

Calculation for Allowable (TMDL) Load from Land Based Sources (MS4 and Non-Point Sources):
= TMDL Load – VPDES Point Source Load Allowable (TMDL)
= $1.57 \times 10^{12} – 2.20 \times 10^{11}$
= 1.35×10^{12} (cfu/day)

Calculation for Allowable MS4 Load:
= 78% of the Allowable Load from Land Based Sources (see Section 5.2.2):
= $.78 \times 1.35 \times 10^{12}$
= 1.05×10^{12} (cfu/day)

Calculation for Allowable LA Load:
= 22% of the Existing Load from Land Based Sources (See Section 5.2.2):
= $.22 \times 1.35 \times 10^{12}$
= 2.97×10^{11} (cfu/day)

Calculation for Percent Reduction Required:
= [(Total Existing Load – TMDL Load)/Total Existing Load] x 100
= [(5.48 x 10^{12} - 1.57 x 10^{12})/ 5.48 x 10^{12}] x 100
= 71%

Calculation for WLA in Table 20:

= VPDES Point Source Load Including Growth + MS4 Load
= 2.20 x 10^{11} + 1.05 x 10^{12}
= 1.27 x 10^{12} (cfu/day)

Calculations for Table 21.

Calculation for Existing Load from Land Based Sources (MS4 and Non-Point Sources):
= Total Existing Load – VPDES Point Source Load
= 5.48 x 10^{12} – 4.39 x 10^{10}
= 5.44 x 10^{12} (cfu/day)

Calculation for Existing Wildlife Load:
= Existing Land-Based Load x .79
= 5.44 x 10^{12} x .79
= 4.29 x 10^{12} (cfu/day)

Calculation for Existing Pet Load:
= Existing Land-Based Load x .20
= 5.44 x 10^{12} x .20
= 1.09 x 10^{12} (cfu/day)

Calculation for Existing Livestock Load:
= Existing Land-Based Load x .01
= 5.44 x 10^{12} x .01
= 5.44 x 10^{10} (cfu/day)

Calculation for Existing Human Load:
= Existing Land-Based Load x .00
= 5.44 x 10^{12} x .00
= 0 (cfu/day)

Calculation for Allowable (TMDL) Load from Land Based Sources (MS4 and Non-Point Sources):
= TMDL Load – VPDES Point Source Load
= 1.57 x 10^{12} – 2.20 x 10^{11}
= 1.35 x 10^{12} (cfu/day)

Calculation for Allowable Wildlife Load:
= Allowable Land-Based Load x .79
= 1.35 x 10^{12} x .79
= 1.07 x 10^{12} (cfu/day)

Calculation for Allowable Pet Load:
= Allowable Land-Based Load x .20
= 1.35 x 10^{12} x .20
= 2.70 x 10^{11} (cfu/day)

Calculation for Allowable Livestock Load:
= Allowable Land-Based Load x .01
= 1.35 x 10^{12} x .01
= 1.35 x 10^{10} (cfu/day)

Calculation for Allowable Human Load
= Allowable Land-Based Load x .00
= 1.35 x 10^{12} x .00
= 0 (cfu/day)

Calculations for Table 23.

Calculation for Existing Load from Land Based Sources (MS4 and Non-Point Sources):
= Total Existing Load – VPDES Point Source Load
= $5.48 \times 10^{12} - 4.39 \times 10^{10}$
= 5.44×10^{12} (cfu/day)

Calculation for Existing Wildlife Load:
= Existing Land-Based Load x .79
= $5.44 \times 10^{12} \times .79$
= 4.29×10^{12} (cfu/day)

Calculation for Existing Pet Load:
= Existing Land-Based Load x .20
= $5.44 \times 10^{12} \times .20$
= 1.09×10^{12} (cfu/day)

Calculation for Existing Livestock Load:
= Existing Land-Based Load x .01
= $5.44 \times 10^{12} \times .01$
= 5.44×10^{10} (cfu/day)

Calculation for Existing Human Load:
= Existing Land-Based Load x .00
= $5.44 \times 10^{12} \times .00$
= 0 (cfu/day)

Calculation for Phase I Reduction Goal
33% = [(Total Existing Load – Phase I Reduction Load)/Total Existing Load] x 100
33% = [(5.48×10^{12} – Phase I Reduction Load)/ 5.48×10^{12}] x 100
= 3.67×10^{12} (cfu/day)

Load from Land Based Sources (MS4 and Non-Point Sources):
= Phase I Reduction Goal Load – VPDES Point Source Load
= $3.67 \times 10^{12} - 2.20 \times 10^{11}$
= 3.45×10^{12} (cfu/day)

Calculation for Allowable Wildlife Load:
= Allowable Land-Based Load x .79
= $3.45 \times 10^{12} \times .79$
= 2.73×10^{12} (cfu/day)

Calculation for Allowable Pet Load:
= Allowable Land-Based Load x .20
= $3.45 \times 10^{12} \times .20$
= 6.90×10^{11} (cfu/day)

Calculation for Allowable Livestock Load:
= Allowable Land-Based Load x .01
= $3.45 \times 10^{12} \times .01$
= 3.45×10^{10} (cfu/day)

Calculation for Allowable Human Load
= Allowable Land-Based Load x .00
= $3.45 \times 10^{12} \times .00$
= 0 (cfu/day)

Calculations for Table 24.

Calculation for Existing Load from Land Based Sources (MS4 and Non-Point Sources):
= Total Existing Load – VPDES Point Source Load
= $5.48 \times 10^{12} - 4.39 \times 10^{10}$
= 5.44×10^{12} (cfu/day)

Calculation for Existing Wildlife Load:
= Existing Land-Based Load x .79
= $5.44 \times 10^{12} \times .79$
= 4.29×10^{12} (cfu/day)

Calculation for Existing Pet Load:
= Existing Land-Based Load x .20
= $5.44 \times 10^{12} \times .20$
= 1.09×10^{12} (cfu/day)

Calculation for Existing Livestock Load:
= Existing Land-Based Load x .01
= $5.44 \times 10^{12} \times .01$
= 5.44×10^{10} (cfu/day)

Calculation for Existing Human Load:
= Existing Land-Based Load x .00
= $5.44 \times 10^{12} \times .00$
= 0 (cfu/day)

Calculation for Allowable Wildlife Load (No Reduction Required):
Allowable Wildlife Load = Existing Wildlife Load
Allowable Wildlife Load = 4.29×10^{12} (cfu/day)

Calculation for Allowable Pet Load (100% Reduction from Anthropogenic Sources):
= Existing Pet Load x 0
= 0 cfu/day

Calculation for Allowable Livestock Load (100% Reduction from Anthropogenic Sources):
= Existing Livestock Load x 0
= 0 cfu/day

Calculation for Allowable Livestock Load (100% Reduction from Anthropogenic Sources):
= Existing Human Load x 0
= 0 cfu/day

Resulting Load if all Anthropogenic Sources are Reduced by 100%:
= Point Source Load + Human Load + Pet Load + Livestock Load + Wildlife Load
= $2.20 \times 10^{11} + 0 + 0 + 0 + 4.29 \times 10^{12}$ (cfu/day)
= 4.51×10^{12} (cfu/day)

Appendix D

Flow Change and Precipitation Analysis

In the interest of better-targeted BMPs for the Neabsco Creek watershed, the correlation between water quality exceedances, stream flow changes, and precipitation was investigated. The goal was to determine which exceedances might be related to runoff and which might be related to direct deposition.

As stated in Section 6.1 of the report, there is no current stream gage on Neabsco Creek. Flow changes and precipitation events recorded at the Washington Reagan National Airport weather station were used as a representation of flow and precipitation events in the Neabsco Creek watershed. Precipitation events on the day before and on the day of each exceedance were examined. Precipitation events on the day before the exceedance were examined to see if decreasing flows on exceedance days were the result of a precipitation event within the preceding 24 hours.

Results of the study are presented in tabular format below.

Table D1. Water quality standard exceedances, stream flow change, and precipitation analysis in Neabsco Creek.

Sampling Date	Fecal Coliform (cfu/100 mL)	Translated *E. coli* Value (cfu/100 mL)	Duration Interval	*E. coli* Load (cfu/day)	Change in Flow From Prior Day (cfs)	Same Day Rain (inches)	Prior Day Rain (inches)
1/25/2001	700	407	61.50	5.38×10^{10}	-0.2	0.0	0.0
1/14/2002	1500	820*	86.70	4.05×10^{10}	-3.1	0.0	0.0
5/6/2002	400	243	65.70	2.87×10^{10}	-6.9	0.0	0.0
7/9/2002	600	353	98.70	2.14×10^{9}	0.0	0.1	0.0
10/26/2005		254	14.10	1.82×10^{11}	-135.4	0.0	0.6
6/21/2006		320	71.60	3.11×10^{10}	-20.1	0.0	0.0
8/28/2007		280	91.50	9.59×10^{09}	-1.3	0.0	0.0
(blue)	Positive flow change with same day or prior day precipitation event.						
(green)	Negative or stable flow change with prior day precipitation event.						
(yellow)	*E. Coli* Data (not transformed)						

Legend (the colours are how the table shows each category):

- Blue cells: Positive flow change with same day or prior day precipitation event.
- Green cells: Negative or stable flow change with prior day precipitation event.
- Yellow cells: *E. Coli* Data (not transformed)

**Maximum exceedance of the E. coli criterion from 2000 to the present. This is the sample that indicates a 71% required reduction needed to reach the TMDL.*

The results of the study suggest that 2 of the 7 exceedances with precipitation data (29%) could have been related to runoff events.

Additional information regarding the nature of the exceedance can be gleaned from looking at the flow conditions under which the exceedances occur. No exceedances occurred during high flows, and only one of the exceedances occurred during transitional flows. Three exceedances occurred during normal flows, and three exceedances occurred in the range of low flows, including the exceedance requiring the highest load reduction.

Appendix E

Soil Descriptions

Map Unit: 1A - Aden silt loam, 0 to 2 percent slopes

Aden is a nearly level to gently sloping, deep or very deep, poorly drained soil. Typically the surface layer is silt loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is slow. It has a moderate available water capacity and a moderate shrink swell potential. This soil is occasionally flooded and is not ponded. The top of the seasonal high water table is at 6 inches. The land capability classification is 3w. The Virginia soil management group is OO. This soil is hydric.

Map Unit: 6A - Baile loam, 0 to 4 percent slopes

Baile is a nearly level to moderately sloping, very deep, poorly drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is slow. It has a high available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 3 inches. The land capability classification is 5w. The Virginia soil management group is HH. This soil is hydric.

Map Unit: 10B - Buckhall loam, 2 to 7 percent slopes

Buckhall is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is V. This soil is not hydric.

Map Unit: 10C - Buckhall loam, 7 to 15 percent slopes

Buckhall is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is V. This soil is not hydric.

Map Unit: 11B - Calverton silt loam, 0 to 7 percent slopes

Calverton is a nearly level to moderately sloping, deep, moderately well drained soil. Typically the surface layer is silt loam about 10 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is slow. It has a low available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 18 inches. The land capability classification is 3w. The Virginia soil management group is BB. This soil is not hydric.

Map Unit: 14A - Codorus loam, 0 to 2 percent slopes

Codorus is a nearly level to gently sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 12 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is frequently flooded and is not ponded. The top of the seasonal high water table is at 18 inches. The land capability classification is 2w. The Virginia soil management group is A. This soil is not hydric.

Map Unit: 15A - Comus loam, 0 to 2 percent slopes

Comus is a nearly level to gently sloping, very deep, well drained soil. Typically the surface layer is loam about 10 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. This soil is frequently flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2w. The Virginia soil management group is A. This soil is not hydric.

Map Unit: 16A - Delanco fine sandy loam, 0 to 4 percent slopes

Delanco is a nearly level to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is fine sandy loam about 11 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderately slow. It has a high available water capacity and a moderate shrink swell potential. This soil is rarely flooded and is not ponded. The top of the seasonal high water table is at 21 inches. The land capability classification is 2e. The Virginia soil management group is B. This soil is not hydric.

Map Unit: 18C - Dumfries sandy loam, 7 to 15 percent slopes

Dumfries is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is sandy loam about 10 inches thick. The surface layer has a low content of organic matter. The slowest permeability is moderately rapid. It has a moderate available water capacity and a low shrink swell potential. This *soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4s. The Virginia soil management group is T. This soil is not hydric.*

Map Unit: 18D - Dumfries sandy loam, 15 to 25 percent slopes

Dumfries is a moderately steep to steep, very deep, well drained soil. Typically the surface layer is sandy loam about 10 inches thick. The surface layer has a low content of organic matter. The slowest permeability is moderately rapid. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 6s. The Virginia soil management group is T. This soil is not hydric.

Map Unit: 18E - Dumfries sandy loam, 25 to 50 percent slopes

Dumfries is a steep to very steep, very deep, well drained soil. Typically the surface layer is sandy loam about 10 inches thick. The surface layer has a low content of organic matter. The slowest permeability is moderately rapid. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is T. This soil is not hydric.

Map Unit: 19B - Elioak loam, 2 to 7 percent slopes

Elioak is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 5 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderately slow. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is X. This soil is not hydric.

Map Unit: 19C - Elioak loam, 7 to 15 percent slopes

Elioak is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 5 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderately slow. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is X. This soil is not hydric.

Map Unit: 20B - Elsinboro sandy loam, 2 to 7 percent slopes

Elsinboro is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is sandy loam about 9 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is rarely flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is L. This soil is not hydric.

Map Unit: 21B - Fairfax loam, 2 to 7 percent slopes

Fairfax is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is D. This soil is not hydric.

Map Unit: 21C - Fairfax loam, 7 to 15 percent slopes

Fairfax is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is D. This soil is not hydric.

Map Unit: 23C - Gaila sandy loam, 7 to 15 percent slopes

Gaila is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is sandy loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is FF. This soil is not hydric.

Map Unit: 23D - Gaila sandy loam, 15 to 25 percent slopes

Gaila is a moderately steep to steep, very deep, well drained soil. Typically the surface layer is sandy loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is *moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is FF. This soil is not hydric.*

Map Unit: 23E - Gaila sandy loam, 25 to 50 percent slopes

Gaila is a steep to very steep, very deep, well drained soil. Typically the surface layer is sandy loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is FF. This soil is not hydric.

Map Unit: 24B - Glenelg-Buckhall complex, 2 to 7 percent slopes

Glenelg is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 5 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is U. This soil is not hydric. Buckhall is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is V. This soil is not hydric.

Map Unit: 24C - Glenelg-Buckhall complex, 7 to 15 percent slopes

Glenelg is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 5 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is U. This soil is not hydric. Buckhall is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is V. This soil is not hydric.

Map Unit: 24D - Glenelg-Buckhall complex, 15 to 25 percent slopes

Glenelg is a moderately steep to steep, very deep, well drained soil. Typically the surface layer is loam about 5 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is U. This soil is not hydric. Buckhall is a moderately steep to steep, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is V. This soil is not hydric.

Map Unit: 25A - Glenville loam, 0 to 4 percent slopes

Glenville is a nearly level to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is slow. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 21 inches. The land capability classification is 2w. The Virginia soil management group is W. This soil is not hydric.

Map Unit: 26A - Hatboro silt **Category:** SOI

Hatboro is a nearly level to gently sloping, very deep, poorly drained soil. Typically the surface layer is silt loam about 14 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is frequently flooded and is not ponded. The top of the seasonal high water table is at 3 inches. The land capability classification is 3w. The Virginia soil management group is HH. This soil is hydric.

Map Unit: 27A - Hatboro-Codorus complex, 0 to 2 percent slopes

Hatboro is a nearly level to gently sloping, very deep, poorly drained soil. Typically the surface layer is silt loam about 14 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is frequently flooded and is not ponded. The top of the seasonal high water table is at 3 inches. The land capability classification is 3w. The Virginia soil management group is HH. This soil is hydric. Codorus is a nearly level to gently sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 12 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a low shrink swell potential. This soil is frequently flooded and is not ponded. The top of the seasonal high water table is at 18 inches. The land capability classification is 2w. The Virginia soil management group is A. This soil is not hydric.

Map Unit: 29B - Hoadly loam, 2 to 7 percent slopes
Hoadly is a gently sloping to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 11 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is very slow. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 12 inches. The land capability classification is 3w. The Virginia soil management group is BB. This soil is not hydric.

Map Unit: 30B - Jackland silt loam, 2 to 7 percent slopes
Jackland is a gently sloping to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is silt loam about 10 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is very slow. It has a moderate available water capacity and a very high shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 18 inches. The land capability classification is 2e. The Virginia soil management group is KK. This soil is not hydric.

Map Unit: 31C - Jackland-Haymarket complex, 7 to 15 percent slopes
Jackland is a strongly sloping to moderately steep, very deep, moderately well drained soil. Typically the surface layer is silt loam about 10 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is very slow. It has a moderate available water capacity and a very high shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 18 inches. The land capability classification is 3e. The Virginia soil management group is KK. This soil is not hydric. Haymarket is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is silt loam about 9 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderately slow. It has a moderate available water capacity and a high shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is KK. This soil is not hydric.

Map Unit: 34C - Lunt loam, 7 to 15 percent slopes
Lunt is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a high shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is AA. This soil is not hydric.

Map Unit: 36D - Marr very fine sandy loam, 7 to 25 percent slopes
Marr is a strongly sloping to steep, very deep, well drained soil. Typically the surface layer is very fine sandy loam about 13 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 6e. The Virginia soil management group is T. This soil is not hydric.

Map Unit: 38B - Meadowville loam, 0 to 5 percent slopes
Meadowville is a nearly level to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 12 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 48 inches. The land capability classification is 2e. The Virginia soil management group is G. This soil is not hydric.

Map Unit: 39B3 - Minnieville clay loam, 2 to 7 percent slopes, severely eroded
Minnieville is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is clay loam about 8 inches thick. The surface layer has a low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not

flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is N. This soil is not hydric.

Map Unit: 39C3 - Minnieville clay loam, 7 to 15 percent slopes, severely eroded
Minnieville is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is clay loam about 8 inches thick. The surface layer has a low content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is N. This soil is not hydric.

Map Unit: 41B - Neabsco loam, 0 to 7 percent slopes
Neabsco is a nearly level to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is very slow. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 21 inches. The land capability classification is 2e. The Virginia soil management group is BB. This soil is not hydric.

Map Unit: 41C - Neabsco loam, 7 to 15 percent slopes
Neabsco is a strongly sloping to moderately steep, very deep, moderately well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is very slow. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 21 inches. The land capability classification is 3e. The Virginia soil management group is BB. This soil is not hydric.

Map Unit: 42B - Neabsco-Quantico complex, 2 to 7 percent slopes
Neabsco is a gently sloping to moderately sloping, very deep, moderately well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is very slow. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The top of the seasonal high water table is at 21 inches. The land capability classification is 2e. The Virginia soil management group is BB. This soil is not hydric. Quantico is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is loam about 13 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is R. This soil is not hydric.

Map Unit: 44D - Occoquan sandy loam, 7 to 25 percent slopes
Occoquan is a strongly sloping to steep, deep, well drained soil. Typically the surface layer is sandy loam about 9 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 6e. The Virginia soil management group is DD. This soil is not hydric.

Map Unit: 44E - Occoquan sandy loam, 25 to 50 percent slopes
Occoquan is a steep to very steep, deep, well drained soil. Typically the surface layer is sandy loam about 9 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is DD. This soil is not hydric.

Map Unit: 45C - Orenda loam, 7 to 15 percent slopes
Orenda is a strongly sloping to moderately steep, deep or very deep, well drained soil. Typically the surface layer is loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderately slow. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is KK. This soil is not hydric.

Map Unit: 47B - Quantico sandy loam, 2 to 7 percent slopes
Quantico is a gently sloping to moderately sloping, very deep, well drained soil. Typically the surface layer is sandy loam about 13 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This

soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 2e. The Virginia soil management group is R. This soil is not hydric.

Map Unit: 47C - Quantico sandy loam, 7 to 15 percent slopes
Quantico is a strongly sloping to moderately steep, very deep, well drained soil. Typically the surface layer is sandy loam about 13 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 3e. The Virginia soil management group is R. This soil is not hydric.

Map Unit: 47D - Quantico sandy loam, 15 to 25 percent slopes
Quantico is a moderately steep to steep, very deep, well drained soil. Typically the surface layer is sandy loam about 13 inches thick. The surface layer has a moderate content of organic matter. The slowest permeability is moderate. It has a moderate available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 4e. The Virginia soil management group is R. This soil is not hydric.

Map Unit: 50D - Spriggs silt loam, 15 to 25 percent slopes
Spriggs is a moderately steep to steep, moderately deep, well drained soil. Typically the surface layer is silt loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a low available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 6e. The Virginia soil management group is JJ. This soil is not hydric.

Map Unit: 50E - Spriggs silt loam, 25 to 50 percent slopes
Spriggs is a steep to very steep, moderately deep, well drained soil. Typically the surface layer is silt loam about 8 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderate. It has a low available water capacity and a moderate shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is JJ. This soil is not hydric.

Map Unit: 51E - Stumptown very flaggy loam, 25 to 50 percent slopes
Stumptown is a steep to very steep, moderately deep, well drained soil. Typically the surface layer is very flaggy loam about 12 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderately rapid. It has a very low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is FF. This soil is not hydric.

Map Unit: 54B - Urban land-Udorthents complex, 0 to 7 percent slopes
Urban Land consists of areas where most of the surface is covered by asphalt, concrete, or other impervious surfaces. Udorthents are areas where the soils have been altered during excavation or covered by earthy fill material.

Map Unit: 55D - Watt channery silt loam, 15 to 25 percent slopes
Watt is a moderately steep to steep, moderately deep, somewhat excessively drained soil. Typically the surface layer is channery silt loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderately rapid. It has a very low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 6e. The Virginia soil management group is JJ. This soil is not hydric.

Map Unit: 55E - Watt channery silt loam, 25 to 50 percent slopes
Watt is a steep to very steep, moderately deep, somewhat excessively drained soil. Typically the surface layer is channery silt loam about 7 inches thick. The surface layer has a moderately low content of organic matter. The slowest permeability is moderately rapid. It has a very low available water capacity and a low shrink swell potential. This soil is not flooded and is not ponded. The seasonal high water table is at a depth of more than 6 feet. The land capability classification is 7e. The Virginia soil management group is JJ. This soil is not hydric.

Map Unit: W - Water
No description available for Water.

Appendix F.

Additional BST Data Collected by Prince William County

Additional BST Sampling Performed in the Neabsco Creek Watershed

During the same time that Prince William County collected BST samples at DEQ Station 1ANEA002.89 (July 2003 to June 2004), they also collected BST samples at five other sites in the impaired portion of the Neabsco Creek watershed, all upstream from Station 1ANEA002.89. While similar to the BST results obtained at station 1ANEA002.89 (located at the outlet of the watershed at the Route 1 Bridge), results from the other five Neabsco Creek/Neabsco Creek Tributary stations did reveal a small human signature in three of the five stations, and a fairly significant livestock signature for the Unnamed Tributary in the top portion of the watershed (Minnieville Elementary School sampling location). This is important to note for purposes of implementation. These samples can help officials involved in the Implementation Plan development to incorporate appropriate BMPs into different parts of the watershed based off the source contribution information obtained from the BST results. Figure F1 shows the location of the Prince William County BST sampling sites in the Neabsco Creek watershed. Tables F1, F2, F3, F4, and F5 show the BST results for the five other BST sampling locations in the Neabsco Creek Watershed.

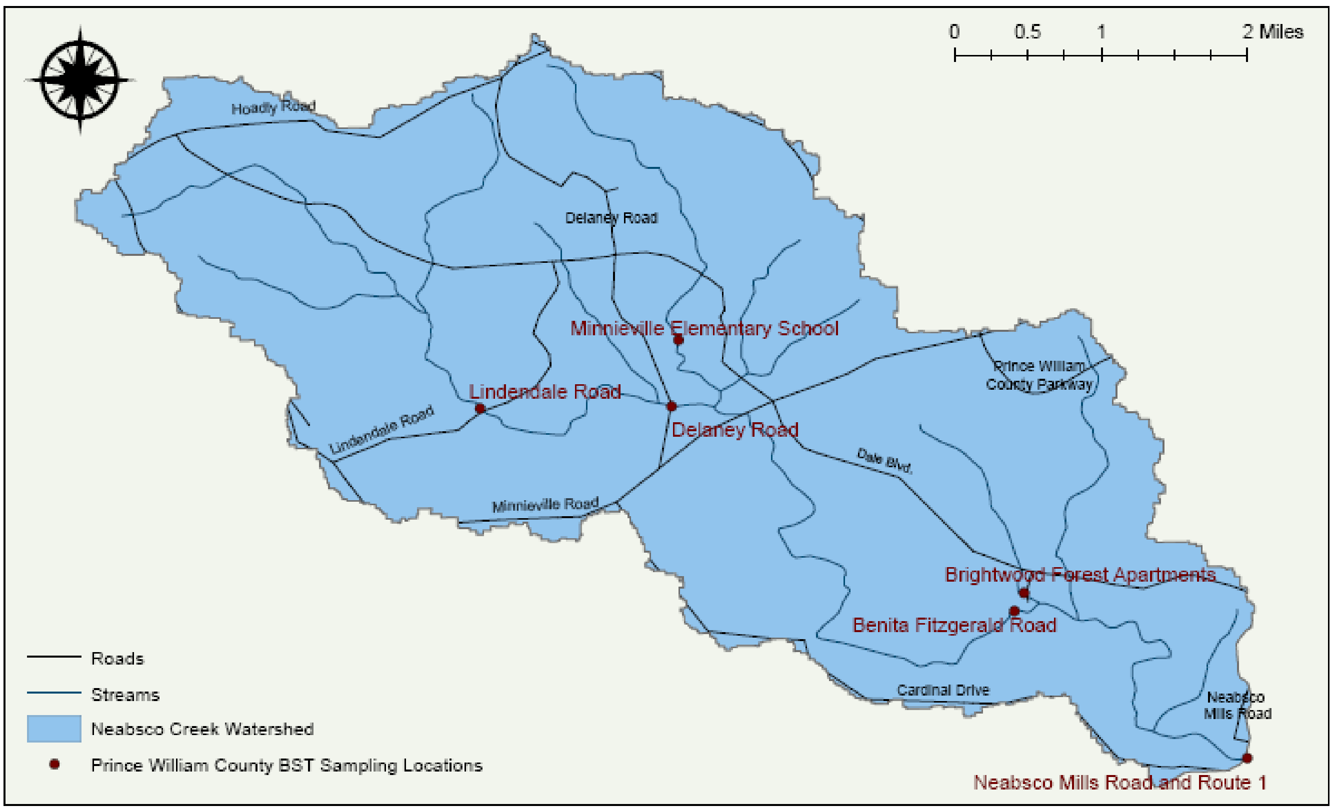


Figure F1. Prince William County BST sampling locations in the impaired portion of the Neabsco Creek watershed.

Table F1. BST sampling results for Delaney Road Station (Neabsco Creek), July 2003 to June 2004.

Collector ID	Sample Date	Flow (cfs)	*E. coli* (cfu/100mL)	*Number of Isolates*	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC	7/9/2003	43.9	3156	24	86%	0%	0%	14%
PWC	8/6/2003	2.5	240	24	72%	0%	0%	28%
PWC	9/5/2003	4.3	NULL	24	NULL	NULL	NULL	NULL
PWC	10/9/2003	2.2	120	24	83%	0%	0%	17%
PWC	11/5/2003	30.1	50	24	79%	4%	0%	17%
PWC	11/7/2003	18.6	1600	24	75%	0%	0%	25%
PWC	12/3/2003	4.0	360	24	88%	8%	0%	4%
PWC	1/7/2004	4.3	135	24	92%	8%	0%	0%
PWC	2/4/2004	14.3	105	24	92%	8%	0%	0%
PWC	3/2/2004	7.8	70	24	88%	8%	0%	4%
PWC	4/6/2004	4.5	30	24	92%	0%	0%	8%
PWC	5/5/2004	4.3	125	24	83%	0%	0%	17%
PWC	6/2/2004	3.5	755	24	65%	0%	0%	35%
				Average:	***83%***	***3%***	***0%***	***14%***

Sample Date	*Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)*				*Annual Weighted Averages (Sum by Category and Divide by Total)*			
	BST Distribution				BST Distribution			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
7/9/2003	2861368.22	0.00	0.00	471460.32	***85.4%***	***0.2%***	***0.0%***	***14.4%***
8/6/2003	10409.84	0.00	0.00	4091.64				
9/5/2003	NULL	NULL	NULL	NULL				
10/9/2003	5220.10	0.00	0.00	1041.50				
11/5/2003	28554.77	1507.26	0.00	5985.66				
12/3/2003	11450.82	1083.92	0.00	542.61				
1/7/2004	9892.96	895.74	0.00	0.00				
2/4/2004	22113.68	2002.25	0.00	0.00				
3/2/2004	4930.22	466.69	0.00	233.62				
4/6/2004	12470.12	0.00	0.00	1129.09				
5/5/2004	64176.23	0.00	0.00	12804.32				
6/2/2004	41389.35	0.00	0.00	22286.57				

Table F2. BST sampling results for Minnieville Elementary School Station (Unnamed Tributary to Neabsco Creek), July 2003 to June 2004.

Collector ID	Sample Date	Flow (cfs)	*E. coli* (cfu/100mL)	*Number of Isolates*	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC	07/09/03	13.3	2205	24	79%	0%	13%	8%
PWC	08/06/03	0.8	120	24	67%	0%	8%	25%
PWC	09/05/03	1.3	1210	24	55%	0%	16%	28%
PWC	10/09/03	0.7	570	24	76%	0%	8%	16%
PWC	11/05/03	9.1	50	24	75%	0%	8%	16%
PWC	11/07/03	5.6	2200	24	79%	0%	0%	21%
PWC	12/03/03	1.2	160	24	84%	0%	8%	8%
PWC	01/07/04	1.3	15	24	96%	0%	0%	4%
PWC	02/04/04	4.3	80	24	100%	0%	0%	0%
PWC	03/02/04	2.4	130	24	100%	0%	0%	0%
PWC	04/06/04	1.4	55	24	96%	0%	0%	4%
PWC	05/05/04	1.3	275	24	92%	0%	0%	8%
PWC	06/02/04	1.1	1200	24	84%	0%	0%	16%
				Average:	***83%***	***0%***	***0%***	***12%***

	Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)				***Annual Weighted Averages (Sum by Category and Divide by Total)***			
Sample Date	BST Distribution				BST Distribution			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
07/09/03	557504.18	0.00	88212.69	58784.93	***78.7%***	***0.0%***	***11.7%***	***9.6%***
08/06/03	1470.38	0.00	175.57	538.99				
09/05/03	20690.52	0.00	6188.35	10702.64				
10/09/03	6892.58	0.00	755.46	1451.07				
11/05/03	8229.76	0.00	914.05	1805.06				
12/03/03	3932.73	0.00	374.55	390.00				
01/07/04	447.70	0.00	0.00	19.45				
02/04/04	8339.49	0.00	0.00	0.00				
03/02/04	7370.20	0.00	0.00	0.00				
04/06/04	1738.12	0.00	0.00	75.50				
05/05/04	7865.82	0.00	0.00	712.20				
06/02/04	25808.51	0.00	0.00	5054.17				

Table F3. BST sampling results for Lindendale Road Station (Neabsco Creek), July 2003 to June 2004.

Collector ID	Sample Date	Flow (cfs)	*E. coli* (cfu/100mL)	*Number of Isolates*	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC	07/09/03	29.6	2094	24	83%	0%	0%	17%
PWC	08/06/03	1.7	1180	24	72%	0%	0%	28%
PWC	09/05/03	2.9	400	24	72%	0%	0%	28%
PWC	10/09/03	1.5	80	24	83%	0%	0%	17%
PWC	11/05/03	20.3	60	24	62%	16%	0%	22%
PWC	11/07/03	12.5	1650	24	70%	4%	0%	26%
PWC	12/03/03	2.7	150	24	79%	17%	0%	4%
PWC	01/07/04	2.9	NULL	24	NULL	NULL	NULL	NULL
PWC	02/04/04	9.6	125	24	83%	17%	0%	0%
PWC	03/02/04	5.2	430	24	92%	8%	0%	0%
PWC	04/06/04	3.0	55	24	92%	0%	0%	8%
PWC	05/05/04	2.9	220	24	84%	0%	0%	16%
PWC	06/02/04	2.4	1680	24	71%	0%	0%	29%
				Average:	***79%***	***5%***	***0%***	***16%***

Sample Date	*Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)*				*Annual Weighted Averages (Sum by Category and Divide by Total)*			
	BST Distribution				BST Distribution			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
07/09/03	1235142.74	0.00	0.00	245540.43	***82.2%***	***0.9%***	***0.0%***	***16.9%***
08/06/03	34501.57	0.00	0.00	13177.68				
09/05/03	19882.26	0.00	0.00	7593.92				
10/09/03	2345.91	0.00	0.00	466.36				
11/05/03	18127.94	4536.66	0.00	6432.50				
12/03/03	7699.50	1608.12	0.00	406.42				
01/07/04	NULL	NULL	NULL	NULL				
02/04/04	24015.26	4774.12	0.00	0.00				
03/02/04	49801.49	4492.96	0.00	0.00				
04/06/04	3698.69	0.00	0.00	333.69				
05/05/04	12757.78	0.00	0.00	2498.40				
06/02/04	67814.10	0.00	0.00	27221.15				

Table F4. BST sampling results for Benita Fitzgerald Drive Station (Neabsco Creek), July 2003 to June 2004.

Collector ID	Sample Date	Flow (cfs)	*E. coli* (cfu/100mL)	*Number of Isolates*	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC	07/09/03	88.5	1607	24	76%	0%	0%	24%
PWC	08/06/03	5.1	120	24	74%	0%	0%	26%
PWC	09/05/03	8.6	510	24	69%	0%	0%	31%
PWC	10/09/03	4.4	210	24	70%	4%	0%	26%
PWC	11/05/03	60.7	50	24	76%	8%	0%	16%
PWC	11/07/03	37.4	1120	24	73%	0%	0%	27%
PWC	12/03/03	8.1	80	24	78%	18%	0%	4%
PWC	01/07/04	8.6	80	24	71%	25%	0%	4%
PWC	02/04/04	28.8	90	24	82%	18%	0%	0%
PWC	03/02/04	15.7	40	24	78%	18%	0%	4%
PWC	04/06/04	9.1	55	24	79%	4%	0%	17%
PWC	05/05/04	8.6	130	24	75%	0%	0%	25%
PWC	06/02/04	7.1	1920	24	72%	0%	0%	28%
				Average	***75%***	***7%***	***0%***	***18%***

	Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)				*Annual Weighted Averages (Sum by Category and Divide by Total)*			
Sample Date	BST Distribution				BST Distribution			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
07/09/03	2595004.64	0.00	0.00	819475.15	***75.6%***	***0.7%***	***0.0%***	***23.8%***
08/06/03	10781.61	0.00	0.00	3788.13				
09/05/03	72633.81	0.00	0.00	32632.58				
10/09/03	15527.70	887.30	0.00	5767.43				
11/05/03	55365.02	5827.90	0.00	11655.79				
12/03/03	12122.03	2797.39	0.00	621.64				
01/07/04	11723.79	4128.09	0.00	660.49				
02/04/04	51074.23	11211.42	0.00	0.00				
03/02/04	11743.21	2709.97	0.00	602.22				
04/06/04	9495.83	480.80	0.00	2043.41				
05/05/04	20124.46	0.00	0.00	6708.15				
06/02/04	234980.80	0.00	0.00	91381.42				

Table F5. BST sampling results at Brightwood Forest Apartments Station (Unnamed Tributary to Neabsco Creek), July 2003 to June 2004.

Collector ID	Sample Date	Flow (cfs)	*E. coli* (cfu/100mL)	*Number of Isolates*	BST Distribution			
					Wildlife	Human	Livestock	Pet
PWC	07/09/03	8.5	1560	24	74%	0%	0%	26%
PWC	08/06/03	0.5	100	24	83%	0%	0%	17%
PWC	09/05/03	0.8	400	24	83%	0%	0%	17%
PWC	10/09/03	0.4	60	24	78%	0%	0%	28%
PWC	11/05/03	5.8	80	24	83%	0%	0%	17%
PWC	11/07/03	3.6	740	24	72%	0%	0%	28%
PWC	12/03/03	0.8	10	24	83%	0%	0%	17%
PWC	01/07/04	0.8	120	24	92%	0%	0%	8%
PWC	02/04/04	2.8	30	24	100%	0%	0%	0%
PWC	03/02/04	1.5	70	24	100%	0%	0%	0%
PWC	04/06/04	0.9	15	24	96%	0%	0%	4%
PWC	05/05/04	0.8	50	24	83%	0%	0%	17%
PWC	06/02/04	0.7	195	24	79%	0%	0%	21%
				Average	***85%***	***0%***	***0%***	***15%***

Sample Date	*Weighted Percentage Calculations (Isolates x Concentration x Flow x Percentage)*				*Annual Weighted Averages (Sum by Category and Divide by Total)*			
	BST Distribution				BST Distribution			
	Wildlife	Human	Livestock	Pet	Wildlife	Human	Livestock	Pet
7/9/2003	235057.60	0.00	0.00	82587.81	***75.1%***	***0.0%***	***0.0%***	***24.9%***
8/6/2003	965.74	0.00	0.00	197.80				
9/5/2003	6567.00	0.00	0.00	1345.05				
10/9/2003	473.75	0.00	0.00	170.06				
11/5/2003	9271.06	0.00	0.00	1898.89				
12/3/2003	154.52	0.00	0.00	31.65				
1/7/2004	2183.72	0.00	0.00	189.89				
2/4/2004	1989.65	0.00	0.00	0.00				
3/2/2004	2524.87	0.00	0.00	0.00				
4/6/2004	301.59	0.00	0.00	12.57				
5/5/2004	820.87	0.00	0.00	168.13				
6/2/2004	2509.40	0.00	0.00	667.06				

Appendix G.

Procedure of Implementing the New Bacteria Criteria in Virginia's TMDL Program
Appendix B of the VA DEQ Guidance Memo No. 03-2012 - HSPF Model Calibration and Verification for Bacteria TMDLs

October 23, 2002

Mr. Thomas Henry

Water Protection Division

USEPA REGION 3 - 3WP13
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Mr. Henry:

This letter is to describe the approach that DEQ and DCR staff have developed to address the transition from fecal coliform (FC) to *E. coli* (EC) as a bacteriological indicator in fresh water.

1. Based on a review of available data and comments from microbiologists, statisticians and modelers (see attachment 1), 493 paired data sets for *E. coli* and fecal coliform from DEQ's statewide monitoring network were used to develop a statewide regression model between FC and EC. The regression model was developed to allow FC data to be translated into EC data during the state's transition period between the two indicators. The regression model is defined as follows:

$$\log_2 EC = -0.0172 + 0.91905 * \log_2 FC$$

The data used to develop the regression model, the statistical software output and a conversion tool from fecal coliform to *E. coli* are provided to you on the enclosed CD.

2. A comparison with regionally grouped data resulted in reasonable approximations up to 100,000 FC #/100 mL (see attachment 2). The statewide regression model is therefore considered appropriate for use in TMDL studies throughout the state.

3. For bacteria TMDLs due to be submitted as part of Virginia's 2004 TMDL commitment, the TMDL endpoint will be based on the new criteria as described in the final regulation published in the Virginia Register on June 17, 2002. For *E. coli*, the applicable single sample maximum criterion should be 235 #/100 mL. This value is subject to revision, pending the issuance of agency guidance for developing single sample maxima based on site-specific data.

The translator should be applied where needed 1) to extend the monitored FC data set for modeling and load-duration TMDLs, and 2) to translate FC model output time series into EC time series in order to determine whether the EC WQS will be met under the TMDL allocation scenario. Attachment 3 contains a flow chart outlining the process for determining the applicable TMDL endpoints based on availability of EC data.

4. The Commonwealth is currently evaluating its options with respect to already completed and approved TMDLs.

I trust that you will find the described approach satisfactory. If you have any questions or need additional information, please contact me or Mr. Charles Martin at (804) 698-4462.

Sincerely,

Alan Pollock
Office of Water Quality Programs

Attachments

Cc: Charles Martin, VADEQ
Jack Frye, VADCR
file

Attachment 1 – Review of Comments

Transition to new bacteria indicator for bacteria TMDLs – Review of Comments

This review of comments presents the results from DEQ's request for comments regarding the transition from the current fecal coliform bacteria criteria to the new *E. coli* criteria in freshwaters of the Commonwealth. As described in DEQ's memorandum dated July 22, 2002, EPA has proposed that a fecal coliform to E. coli translator should be used "to insure that the allocations will attain the future bacteriological standard". EPA also proposed using such a translator to extend the E. coli data set used for TMDL development.

Following the TMDL committee meeting on July 19, 2002, DEQ requested Drs. Chuck Hagedorn and Bruce Wiggins, both microbiologists, Dr. Eric Smith, a statistician, and Dr. Gene Yagow, a TMDL developer, to evaluate four options for such a translator. Additional comments were provided by Dr. Mike Scanlan and Ron Phillips, both with VADEQ. The evaluators' responses are summarized in the table provided below. A review of the evaluators' assessments revealed the following:

- Of the four options, Options 1 and 4 were most favored by the reviewers. Option 1 uses a large statewide data set while Option 4's benefit is its localized (but smaller) data set. Option 1 can also be implemented quickly and will require less resources than Option 4. The reviewers suggested an improved regression model using the statewide data set, but allowing for site-specific modifications if the local data warrant or require it.

- Option 2, while easily understood and presentable to the public, was not generally favored. It was not considered sufficiently developed and the ratio between EC and FC has been shown to vary. Also, that option presents EC and FC ratios based on a single agar plate. This method is not compatible with the analytical techniques used in the ambient monitoring program.

- Option 3 was generally dismissed because it is not based on an observed relationship between actual data.

At the TMDL committee meeting on August 9, 2002, it was decided to refine the statewide regression model by including all available data, adding site and region codes to allow data grouping, and developing linear regressions (EC vs. FC) on log-transformed data. It was also agreed to further discuss the application of such a translator in the case of already completed TMDLs, as proposed by EPA.

Table 1: Comment Summary (Yagow, Hagedorn, Wiggins, Smith, Scanlan, Phillips*)*

	Option 1: Based on counts from separate E. coli/FC analyses	Option 2: based on counts from combined E. coli/FC analyses	Option 3: based on EPA bacteria criteria	Option 4: To be based on counts from separate E. coli/FC analyses
Positive	- most scientifically valid - largest # samples - statistically based - good choice as long as data set is suitable	- easy to present to public - easy to understand by public - suitable if E. coli (EC) is determined from same plate as fecal coliform (FC)	- easy to present to public - easy to understand by public - adequate - simplest, most defendable if underlying data set is appropriate	- site-specific data generally preferred by public - data collection is already planned
Negative	- most difficult to explain - not suitable for data above/below DL - not based on local data - uses only data from lower concentration range	- conflict with Option 3 - %age is in conflict with Mountain Run study (38-47%) - VT and JMU work not suitable for use - VT data from source, not water samples	- conflict with Option 2 - simplistic, no observed data - less desirable than 1 and 4 due to variability in EC/FC ratio - lower than observed - higher than observed	- few data points - limited data range
Suggestions	→ use with Option 4 to cross-validate → use linear regression of log of counts → remove outliers → expand data set			→ use with Option 1 as cross-validation → use as refinement to Option 1, 2 or 3 → expand data set

Note: Conflicting comments reflect the opinions of the various commenters.

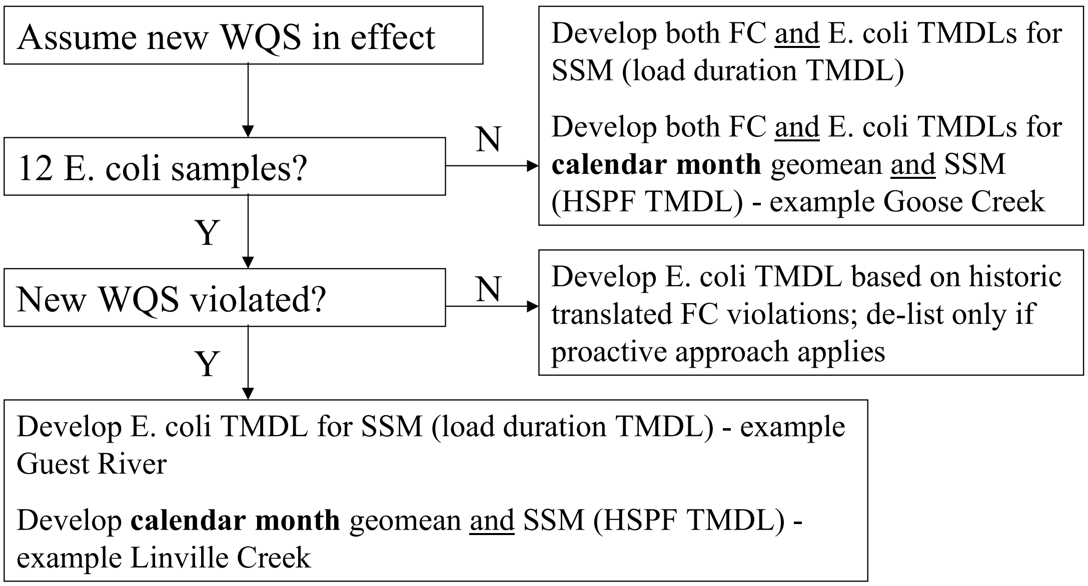
Attachment 2 – Regional Translator Comparison

FC conc	Resulting EC conc for			
	Statewide N = 493	02070005 N = 175	03010101 N = 122	05050001 N = 39
10	8	8	8	9
	0.00%	0.00%	0.00%	-12.50%
100	68	69	69	70
	0.00%	-1.47%	-1.47%	2.94%
190	123	124	124	123
	0.00%	-0.81%	-0.81%	0.00%
200	129	130	129	129
	0.00%	-0.78%	0.00%	0.00%
400	243	245	243	237
	0.00%	-0.82%	0%	2.47%
1,000	565	564	561	530
	0.00%	0.18%	0.71%	6.19%
2,000	1,068	1,061	1,055	975
	0.00%	0.66%	1.22%	8.71%
10,000	4,688	4,600	4,573	4,011
	0.00%	1.88%	2.45%	14.44%
100,000	38,911	37,503	37,281	30,332
	0.00%	3.62%	4.19%	22.05%

% indicates statewide result compared to regional result

Attachment 3 – Bacteria Indicator Implementation Flow Chart

Proposed Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs



Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Goose Creek

- HSPF modeling TMDL
- Draft Oct 02, final Dec 02
- No E. coli data
- Assume new WQS in effect
  - develop FC TMDL <u>and</u> E. coli TMDL
  - address both calendar month geometric mean and single sample maximum criteria
  - use implicit MOS
  - WLA: should reflect both criteria

Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Linville Creek

- HSPF modeling TMDL
- Draft Nov 02, final Dec 02
- >12 E. coli data
- Assume new WQS in effect
  - develop E. coli TMDL only
  - address both calendar month geometric mean and single sample maximum criteria
  - use implicit MOS
  - WLA: should reflect both criteria

Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Guest River

- Load Duration TMDL
- Draft Sept 03, final Dec 03
- 12 E. coli data
- Assume new WQS in effect
  - develop E. coli TMDL
  - address single sample maximum criterion only
  - use implicit MOS
  - WLA: should reflect SSM criterion